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REPORTS ON THE CONTRIBUTION OF SURVEYING, MAPPING AND CHARTING TO SUPPORT THE IMPLEMENTATION OF AGENDA 21: OTHER APPLICATIONS OF SURVEYING AND MAPPING TO SUPPORT THE IMPLEMENTATION OF AGENDA 21

Building a Production System to Support the National Digital Orthophoto Program: An Integration Challenge**

(Submitted by the United States of America)

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** Prepared by George Y. G. Lee and David C. Hooper, U.S. Geological Survey.

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BUILDING A PRODUCTION SYSTEM TO SUPPORT THE NATIONAL DIGITAL ORTHOPHOTO PROGRAM: AN INTEGRATION CHALLENGE

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INTRODUCTION

The goal of the National Digital Orthophoto Program (NDOP) is to produce digital orthophoto coverage of the conterminous United States by the year 2001. A steering committee composed of Federal agencies and State organizations provides oversight and technical leadership for the program. The U.S. Geological Survey (USGS) is responsible for administering the program. The production strategy is to accomplish the majority of the work by contracting to firms in the private sector. This contracting strategy introduces a need for quality control tools within the production system. The digital orthophoto production system developed by the USGS in support of the digital orthophoto program evolved from a feasibility study and a prototype system. At the time, commercial software was not available in the United States to produce digital orthophotos.

BACKGROUND

The USGS, National Mapping Division, began producing analog orthophotos in 1964 using custom-built orthophoto equipment developed within the agency. For the next 25 years, the agency produced analog orthophotos that often provided users with the only accurate base map in areas where the 7.5-minute topographic maps did not exist. During this period, the USGS also used three generations of commercially manufactured orthophoto equipment.

In the late 1970's, the agency began its digital data programs that included digital elevation data as well as digital line graph data. The digital elevation data were collected, resampled, and formatted as a by-product of the analog orthophoto production process. In 1985, the National Mapping Division began its development of the current digital orthophoto system through a feasibility study made at its Western Mapping Center that demonstrated the generation of digital orthophotos from scanned diapositives using a minicomputer. Sample digital orthophoto products were created over the next several years and although they were received with much interest, there were no demands for a production implementation of the prototype system. A pilot project in Dane County, Wisconsin, which was presented at the first National Digital Orthophoto Forum in 1990, provided the impetus for nationwide coverage of digital orthophotography.

During the development period, the agency produced analog orthophotos using the Wild OR-1 orthophoto system*. The general lack of standards for analog components of the production process extended the development time for the system and ultimately required a system modification as

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standards were redefined. Furthermore, the transition period from an analog orthophoto generation process to a digital process created a legacy of digital and nondigital components, which added to the integration problem. Finally, new requirements and technology changes introduced new integration issues. This paper describes the evolution of the current production system and its current capabilities.

PRODUCTION STRATEGY

The demand for digital orthophotos increased due to the maturity of GIS technology, the general lack of current base cartographic data, and the dramatic drop in computer hardware costs. This sudden demand for digital orthophoto data could not be met with existing resources and budget levels. Pooling of government resources and relying on private industry were practical solutions to the budget limitations and the limited production capacity.

SYSTEM AND DESIGN CONSTRAINTS

Although the USGS had long abandoned any in-house photogrammetric hardware development, the agency continued software development to perform system integration tasks. For the digital orthophoto development, the USGS expanded its prototype software into a digital production system because commercial software was not available. However, the system design was for a modest amount of production work because the production strategy was to accomplish the majority of the work by contracting to firms in the private sector.

The basic inputs to the present system are (1) diapositives generated from available photography acquired from the National Aerial Photography Program (NAPP), (2) camera calibration data, (3) existing photoidentified control from previous mapping projects, (4) aerotriangulation data in different formats, (5) existing digital elevation model (DEM) data from the National Digital Cartographic Database, and (6) topographic maps (fig. 1, box A).

The National Aerial Photography Program is a cooperative program with State and Federal agencies to acquire color-infrared or black-and-white aerial photography over the conterminous United States on a cyclic basis. Photography from this program is the primary source imagery for the digital orthophoto program and diapositives are generated from the original aerial film. In this scenario, the aerial photography has already been inspected using strict standards. However, there are many instances where existing photography is not suitable for the requirements of the orthophoto user. In these situations, the aerial photography is acquired by the mapping contractor as part of the digital orthophoto contract. In this second scenario, inspection of the newly acquired photography is required before production of the digital orthophoto begins. The two scenarios presents two dataflow paths through the production process. In-house production scanning also presented two dataflow paths because diapositive scanning was performed on two scanners made by different manufacturers, which required slightly different data handling.

Since the USGS has the responsibility for camera calibration in the United States, the necessary camera calibration information is readily available for in-house production purposes. However, the

current USGS camera calibration process does not provide the calibration results in digital form to the contractors or to the general public. In general, users are required to manually enter camera calibration data into their orthophoto rectification systems.

Where feasible, photoidentified control points from previous mapping projects are used to reduce the cost for additional field control. The use of these data constrains this portion of the production system to be analog because these data are obtained entirely from analog techniques.

When available, digital elevation data from the National Digital Cartographic Database were extracted and used in the orthophoto generation. However if digital elevation data were not available, they were generated by photogrammetric methods or derived from digitized hypsographic data. This represented two additional dataflow paths.

ADDITIONAL DESIGN REQUIREMENTS

In addition to producing the standard 3.75- × 3.75-minute digital orthophoto quadrangles (DOQ's), mosaicking of DOQ's into the traditional 7.5- × 7.5-minute quadrangle format and limited hardcopy image output was necessary for specific needs. Data delivery requirements include archiving in a format for easy use in various GIS systems while providing sufficient metadata for data management purposes. These requirements also include using a compression algorithm that is in the public domain and available on various computer platforms, and distributing the data on various media.

STANDARDS DEVELOPMENT

Since digital orthophoto data are to be generated by other agencies and private contractors, there is an obvious need for DOQ standards (fig. 1, box B and C). Currently two standards are being developed in the United States. The USGS has been working with participants of the National Digital Orthophoto Program to develop standards for the digital orthophoto (U.S. Geological Survey, 1995). Meanwhile, each Federal agency also participates on the Federal Geographic Data Committee to develop digital orthophoto standards for the National Spatial Data Infrastructure (Federal Geographic Data Committee, 1995). Unfortunately, an accepted national standard was not available before system development began. Furthermore, the long review process and the iterative changes to the draft standard complicated the system development effort and prolonged the development period.

Digital orthophoto production by other agencies and contractors also adds a functional requirement that the digital production system validate data deliverables from all data producers to ensure that the product meets standards. These data include field control, airborne GPS, aerotriangulation data, DEM's, digital orthoimagery, digital orthophoto metadata, orthophoto mosaics, and hardcopy (fig. 1, box D). System design and integration were more complex because there were no standards for many of these data elements.

DATABASE CONSIDERATIONS

In addition to several iterations of standards changes, the database approach for the National Digital Orthophoto Program also changed. This necessitated reprocessing of data in the archive. The USGS changed from a centralized archive to a decentralized database for all its data holdings. Operational databases (ODB) were established within regional production centers for their respective data responsibilities. Furthermore, a sales database (SDB) was implemented for distribution of data to the general public (fig. 1, box E). The transition from a centralized model to a decentralized model altered the dataflows and further affected the system development activity.

CONCLUSIONS

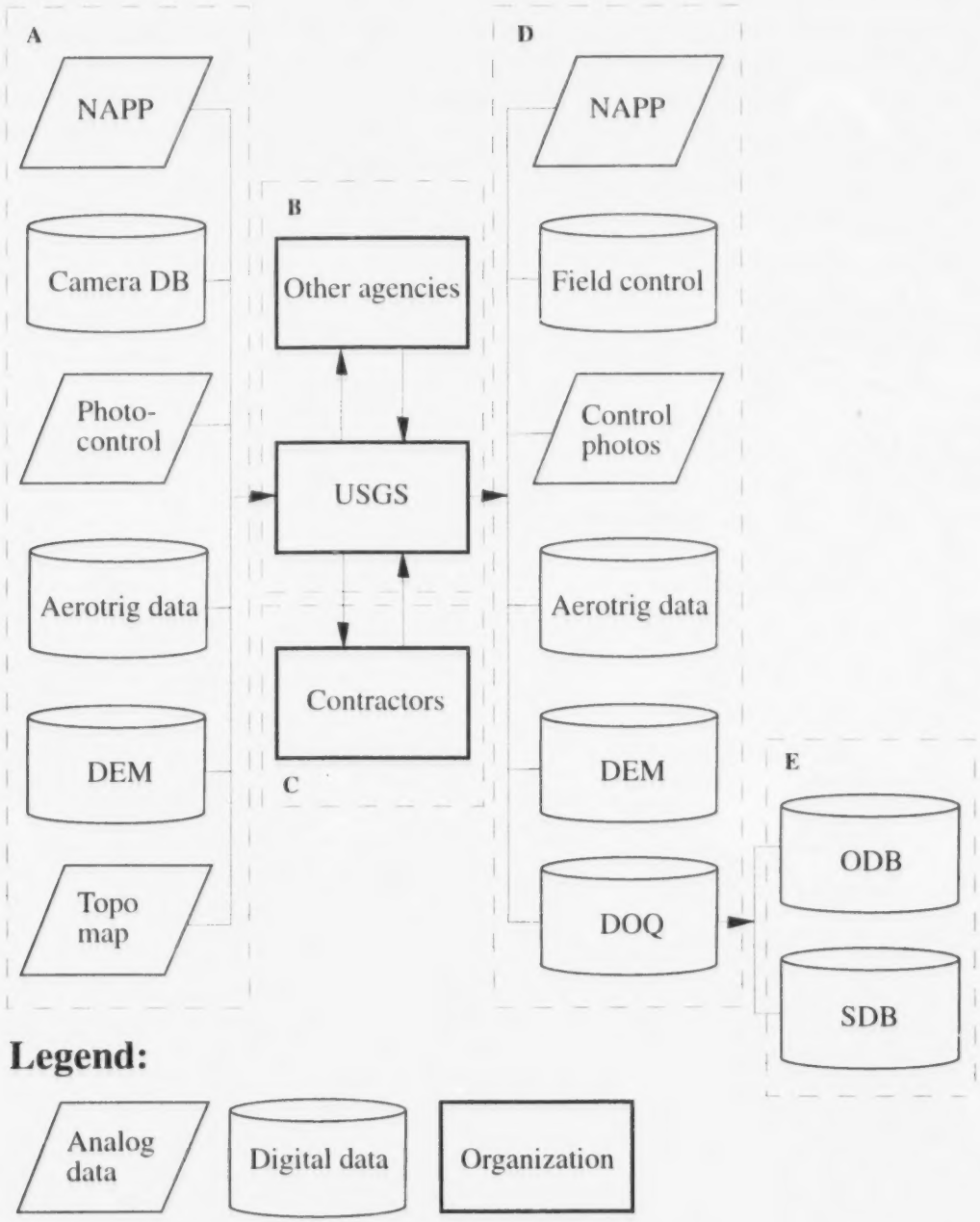

Figure 1. Digital orthophoto production system dataflow.

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Budget constraints imposed additional complexities to the design task because each hardware component was procured on separate contracts over a period of several years and system integration was performed entirely by in-house personnel. The sudden demand for a production system, the general lack of standards, constantly changing requirements, a mixture of analog and digital inputs, a multivendor hardware environment, and budgetary constraints were all factors in making the development of the digital production system an integration challenge.

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* Any use of trade, product, or firm names is for descriptive purposes only and does not imply endorsement by the U.S. Government.

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Recent Experience in Mapping Land Cover from AVHRR Data: People's Republic of China Test Sites**

(Submitted by the United States of America)

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RECENT EXPERIENCES IN MAPPING LAND COVER FROM AVHRR DATA: PEOPLE'S REPUBLIC OF CHINA TEST SITES

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INTRODUCTION

There are well-documented needs for small-scale (1-km) land cover data for use in national to global environment assessments [1]. While there is general acceptance that 1-km data from the Advanced Very High Resolution Radiometer (AVHRR) are the most appropriate imagery for mapping land cover over large areas, the practical understanding of the consistency of results in different landscapes is limited. For AVHRR to be used effectively throughout the globe, it is necessary to understand the environmental and technical factors that influence the quality of results. To better understand these factors, researchers from the People's Republic of China (PRC) National Bureau of Surveying and Mapping (NBSM), the U.S. Geological Survey (USGS), and the University of Nebraska-Lincoln mapped land cover for two test sites in China. This collaboration was conducted as part of a formal protocol between the NBSM and USGS.

STUDY SITES CHARACTERISTICS

The two sites, in the north central and south east regions of the country, differ in climate, vegetation, and land use intensity. The north central site encompasses an area from 31 N to 41 N and 101 E to 115 E. It includes all or portions of Shanxi, Shaanxi, Hubei, Henan, Gansu, Sichuan provinces and the autonomous region of Inner-Mongolia. Three physiographic regions can be identified in the area: a temperate desert and semi-desert environment in the north west, a mosaic encompassing the Loess Plateau, a series of mountains and inter-mountainous basins, and several fluvial plains in the east, and the Tibetan Plateau in western Sichuan province. The south east site lies between 24 N to 28 N and 108 E to 114 E, including portions of Hunan, Guangxi, Guangdong, Guizhou, and Jiangxi provinces in southeastern China. This region is in the subtropical monsoon climate zone, and is an area heavily influenced by cultivation and socio-economic development.

DATA

Primary data used in this study are the NOAA AVHRR 1 km Normalized Difference Vegetation Index (NDVI) composites for the 1992 growing season. The NDVI composites were compiled by the USGS EROS Data Center [2]. Seven monthly composites (from April through October) were acquired initially for the two study areas. Because of excessive cloud-contamination in some monthly composites, a decision was made to combine six monthly composites into three bi-monthly composites for the north central site (i.e. April-May, July-August, and September-October). For the same reason, two monthly composites (July and October) for the south central site were not included in this study. Besides NDVI data, a digital elevation model (1:4,000,000) of the study area was provided by NBSM, and a digital soil database was acquired from the Remote Sensing Center, Beijing Agricultural University, China. An atlas of China land use (1:1,000,000), compiled by the Institute of Geography, Chinese Academy of Sciences in 1980, was referenced to aid land cover interpretation [3].

LAND COVER CLASSIFICATION PROCEDURE

The land cover classification procedure utilized in this experiment drew from experience by land cover characterization research conducted by the USGS EROS Data Center and the University of Nebraska-Lincoln [4]. Several steps were taken to derive seasonally-distinct land cover regions from the NDVI time series and other ancillary data. The initial classification using NDVI composites was accomplished with an unsupervised clustering algorithm and minimum-to-mean-distance classifier implemented in the Land Analysis System (LAS) image processing package. More than eighty clusters were generated for two test sites and their statistics were computed for further analysis.

RESULTS AND ANALYSIS

Class labeling and refinement using ancillary data--Temporal NDVI profiles were examined for initial class labeling in relating some clusters to major land cover types (e.g., desert and semi-desert steppe, cropland, grassland, and forest). However, some clusters could not be readily labeled based on NDVI profile alone due to spectral-spatial confusions among land cover types. The confusion was primarily related to variations in vegetation phenology and topographic feature. Among the mixed classes, two types of clusters were distinguished: 1) clusters composed of two or more cover types coexisting within a similar environment, and 2) clusters corresponding to two or more cover types with each type occurring at different locations. Clusters of the second type were refined using ancillary data. For instance, cluster 9 in the north central site occurred in two geographic regions: the east section with predominant lowland agricultural land use, and the southwestern section located in the Tibetan Plateau. Accordingly, the cluster was split into dryland cropland and subalpine meadow based on elevation and geographic location. Cluster 25 covered both paddy fields and forest. The cluster was split by

intercepting the class with paddy soil categories. Cluster 28 contained plain irrigated cropland, terraced paddy and slope grassland. Based on documentation of local environment [3], most plain cropland is located below 600 meters, the terraced paddy in between 600 to 1500 meters, and slope grassland above 1500 meters. Thus, digital elevation data were used in this case to split cluster 28 into three classes. A similar process was also applied to the south east site in post-classification.

The final classification yielded 26 distinct land cover types for the north central area and 16 classes for the south east site. Table 1 lists 18 major land cover categories identified from this study.

Table 1. Land Cover Classes

Class ID	Class Label
1	irrigated cropland (paddy)
2	irrigated dryland cropland
3	non-irrigated cropland
4	coniferous forest
5	deciduous forest
6	mixed forest
7	sparse woodland
8	firewood and bush
9	meadow
10	steppe
11	alpine and sub-alpine meadow
12	slope grassland
13	sandy desert
14	bare ground/sparsely vegetated land
15	woodland/grassland
16	woodland/cropland
17	woodland/bamboo/grassland
18	tree crop/woodland

Effect of cloud on classification--The presence of cloud and atmospheric haze caused some problem for the classification. Approximately one third of the total clusters (15 out of 46) in the south east site were affected by clouds. Low NDVI values (<0.15) were recorded for some forest area during the mid-growing season. For instance, class 25 is coniferous forest which is the same cover type as class 26 and 29; yet its NDVI of August is significantly different from the latter two classes (0.46 versus 0.15, 0.10). The severe cloud-contamination on the NDVI is related to the monsoon rainy season of the area, which can last for long period during growing season. This problem is a recurring issue for large area land cover mapping using AVHRR data and needs to be further addressed.

Heterogeneity of land cover--In general, broad land cover patterns were adequately defined in both test sites. However, identification of detailed land cover types was uneven, especially for the south east test site. The classification of this area was

comprised of a significant number of mosaic categories that often included disparate land cover types. This was the result of extremely complex and fragmented land cover patterns resulting from topographic influences and intense human activity. The heterogeneity of land cover in this area necessitates the inclusion of several mixed (or mosaic) cover categories in the final classification (Table 1). For the northern site, the mixed land cover types include cropland/grassland, cropland/woodland, cropland/woodland/grassland. The south east site identified several unique mixed cover types (grassland/tree-crop, forest/bamboo/grassland), in addition to those found in the northern site.

Special land cover classes--The identification of small paddy fields and bamboo forest in the south east site was a challenge. These cover types are often spectrally and spatially mixed with others, and therefore, are difficult to separate. In some area, the difficulties can be eased by using ancillary data. In eastern Hunan province, for instance, paddy fields were satisfactorily extracted using slope and soil data (slope < 1 degree, and soil type). One extensive bamboo forest area in this site was separated from other mixed grassland/woodland using elevation data. In contrast, other bamboo mixed classes were not separable due to a mixture with forest and grasslands. The inconsistency in occurrence of location and highly interspersion of those cover types make them difficult to identify.

Smoothing process--Because of the complex land cover patterns of the south east test site, the final land cover classification was further processed using a smoothing procedure developed by NBSM scientists. The smoothing process was based on mathematical morphology, noise cleaning, and region/neighborhood analysis. This method effectively generalizes the classification and allows the dominant regional land cover to be expressed. This procedure also facilitates the inclusion of the results into geographic information systems.

DISCUSSION AND SUMMARY

This experiment has demonstrated that large area land cover mapping in north central and south east China using NOAA AVHRR 1-km NDVI composite data is feasible. Qualitative comparison of the results with the 1:1,000,000 China land use/cover maps [3] suggested that major land cover types can be adequately mapped with AVHRR NDVI data aided by digital elevation model, soil database and other ancillary data. Several observations were made with regard to what has learned from this experiment.

The characteristics of the physical environment and land use practices of the two test areas had significant impact on the classification outcome and on post-classification strategy. For the north central site, distinct spatial differentiation in local climate, soil properties, and topography allows major land cover types to be readily identified on the classified image. In contrast, the extremely complex and fragmented land cover/land use patterns of the south east site imposed considerable difficulties in identifying certain land cover classes. In some cases, the same land

cover types with different temporal NDVI were classified into several groups due to variation in plant phenology, geographic location, and local topography. Conversely, some different land cover types had similar NDVI temporal profiles and were classified into a single cluster. Under such circumstances, availability of ancillary data and information on the local environment become essential in formulating post-classification strategy in order to refine class labeling. In this study, the digital elevation model and soil data base were particularly useful in post-classification stage.

The effects of cloud-contamination on land cover classification has been an issue addressed by researchers. In the present study this problem was particularly noted in the south east test site, a region with subtropical monsoon climate. Because the growing season of the area corresponds to the rainy season, even the monthly NDVI composites are not adequate to generate usable data for some months. Research on development of robust cloud screening methods and techniques for mitigation of cloud-contamination for AVHRR data are warranted. Until such methods are available, the quality of the land cover mapping in the extreme cloud-prone regions may be necessarily compromised.

This study also suggests a need for developing an appropriate hierarchy for describing highly mixed land cove types. The mosaic and extreme fragmented land cover patterns in southeastern China is the rule rather than exception. The diverse land use patterns and frequent changes in spatial composition of cover types demand careful considerations in class labeling and post-classification as well as presentation of the results.

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Standards for the Global Spatial Data Infrastructure (GSDI)**

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STANDARDS FOR THE GLOBAL SPATIAL DATA INFRASTRUCTURE (GSDI)

Introduction

Over the past two decades, the introduction of computers to the geographic community has progressed from the automation of manual techniques in cartography to the analysis of spatial data by geographic information systems (GIS). A GIS is an information system which answers the fundamental question of where? In general, geographic information systems organize, analyze, and display spatial data. Beyond producing computer maps, a GIS performs spatial analysis and complex queries. GIS serves as an enabling technology because so much data is inherently spatial through geo-referencing by a coordinate system or set of alphanumeric codes.

The integration of technological advances in computer hardware and software capabilities with mapping and analytical functionality in conjunction with decreasing costs have led to rapid rise and use of GIS technology. GIS capabilities are beginning to be integrated into mainstream information technologies. For example, within the context of a spreadsheet application containing data associated with numerous cities within a country, a simple function would be to selectively display their locations on a map as an option. Portable Global Positioning Systems (GPS) receivers record geographic locations from anywhere on the earth and are used in surveying, mapping, and navigation systems for land vehicles, planes, and ships. The geographic community has invested considerable resources into the conversion of analog spatial data, such as paper maps, into digital form. Satellites, using a variety of sensors, will provide a new and abundant source of spatial data. Optical and radar satellite imagery are important for updating maps and/or originating digital spatial databases Such systems will provide terabytes of spatial data in digital form directly, without the lengthy and costly

process of analog to digital conversion, to the geographic community and the information technologies incorporating GIS functionality.

Currently, the declining cost of producing and using spatial data is intensifying the need to share and integrate spatial data. Hence, the availability, accessibility, management, and integration of digital spatial data is becoming a major challenge to the GIS community of data producers, software vendors, systems integrators, and users. Increasingly, the international response to this challenge is the formation of spatial data infrastructures.

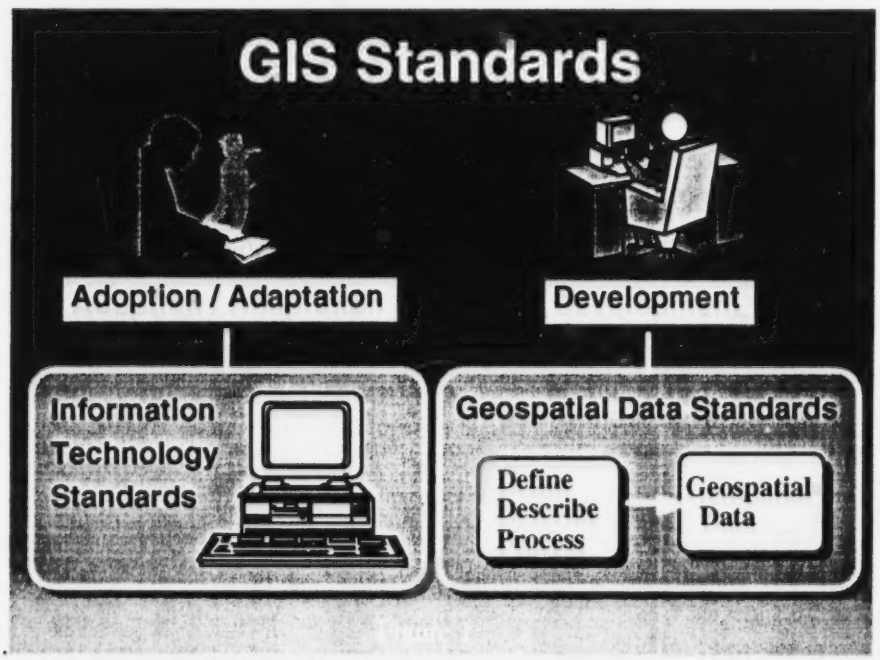
Spatial Data Infrastructures

Spatial data infrastructures (SDI) at the national and regional levels are collectively stimulating the emergence of the global spatial data infrastructure. A spatial data infrastructure for a country is considered a national spatial data infrastructure (NSDI), which can vary by country. A regional spatial data infrastructure (RSDI) is comprised of several NSDIs or by a number of countries, in which a country may or may not have its own NSDI. Accordingly, the global spatial data infrastructure is formed by linking national and regional spatial data infrastructures.

Four elements are emerging as major components of a spatial data infrastructure, common to each level of the global spatial data infrastructure. The four components are: ***technology, standards, policy, and institutional framework***. For technology: there was acknowledgment that GIS technology is founded upon generic information technology, which accentuates the need for GIS technology to be fully integrated with the emerging Global Information Infrastructure (GII). For standards: GIS standards are also based on information technology standards and that the GIS standards infrastructure needs to be understood, adopted, and utilized within the broader structure of a spatial data infrastructure. For policy: many policies need to be developed, with an international viewpoint, regarding all aspects of data. For institutional framework: agreements must be ratified for coordinating the formation and linking of national and regional spatial data infrastructures to form the global spatial data infrastructure.

Another important aspect of the global spatial data infrastructure is the concept of ***framework data***. Framework data are those basic datasets upon which most other datasets could be built. Some of the basic datasets identified include: geodetic, cadastral, hydrography, transportation, boundaries, elevation, and digital orthoimagery datasets. It was quite apparent that the underlying dataset for framework data is the *geodetic network*, which provides consistent global geo-referencing for spatial datasets created or derived.

Internationally, there is consensus in recognizing the importance of GIS standards. The correspondence of levels between the GIS standards infrastructure and those of the global spatial data infrastructure facilitates the integration of spatial data. GIS standards can integrate horizontally across a spatial data infrastructure level and vertically integrate between various levels. GIS standards provide the horizontal integration of spatial data at each of the federal government, municipal, county, and state levels and provide the vertical integration of these levels to form the national spatial data infrastructure. Similarly, GIS standards also provide the horizontal integration of spatial data across each of the national and regional levels, while providing the vertical integration of these levels to form the global spatial data infrastructure. Equally significant, the global spatial data infrastructure serves a major role in the development, deployment, and implementation of international GIS standards. The success of standards, in turn, determines the viability of the global spatial data infrastructure. Consequently, a basic understanding of GIS standards and the GIS standards infrastructure is vital.



GIS Standards

GIS standards are comprised of both information technology standards and spatial data standards. Information technology standards are either adopted in total or adapted with modification. Spatial data standards are developed to define, describe, or process spatial data. (Figure 1) During the past decade, GIS standardization was focused on developing a spatial data interchange

standard. This effort, however, was made by over two dozen countries and international organizations. As a result, several spatial data interchange standards exist. Because this was the first standardization effort within the GIS world, it required a long time to overcome an atmosphere of reluctance and to establish a mindset receptive to standardization within the GIS community. This change in attitude is the true value of these initial efforts in standardization. The GIS community is now accepting standards, such as the forthcoming metadata standard. In conjunction with this acceptance, three trends in GIS standardization have evolved.

First, the development of GIS standards should be anticipatory. Standards developed as a reaction to a problem are usually too late because of the lengthy development time and equally long if not longer time required for approval. The time span required for approval generally reflects the extent of consensus needed. If standardization occurs too late, resistance from established providers and users can derail any coherent resolutions. Timing in standardization is critical. If standardization occurs too soon, it can stifle innovation or even lead technology away from its own course of evolution. Effective standardization requires foresight and begins before the needs and problems arise.

Secondly, the development of GIS standards now includes the participation of end users. GIS users are not only concerned about the interoperability of hardware and software, they are specifically addressing the interoperability of data - in terms of terminology, syntax, and semantics. GIS users, having reached a level of maturity and sophistication, are aware that many of the spatial data standards to be developed, in large part, will be implemented and used by GIS data producers and users.

Thirdly, GIS standards need to be integrated. The GIS community recognizes that standards will be used more as an integrated set of standards than just a number of stand alone standards. Several emerging standards such as the metadata standard and data quality standard will be incorporated as parts of other forthcoming standards.

Globally, the development of GIS standards is occurring at government, national, regional and international levels. This development is not confined to just standards organizations which formally develop and approve standards. Substantial efforts are being made in various user/applications communities. Some user/applications communities may develop standards, while others endorse and/or adopt GIS standards. These communities are, in fact, the user community for GIS standards. There is a definite need to coordinate this development from the standpoints of integration and division of labor to avoid duplication and incompatibility. Collectively, these organizations and efforts form the GIS standards infrastructure which needs

to be understood and incorporated into the hierarchy of spatial data infrastructures.

GIS Standards Infrastructure

Standards Organization	Scope of Standards	User Organizations
National Institute of Standards and Technology (NIST)	Government	Federal Geographic Data Committee (FGDC)
American National Standards Institute (ANSI)	National	Open GIS Consortium (OGC) National States Geographic Information Council (NSGIC)
European Committee for Standardization (CEN)	Regional	Digital Geographic Information Working Group (DGIWG) European Umbrella Organization for Geographic Information (EUROGI) Permanent Committee on GIS Infrastructure for Asia and the Pacific
International Organization for Standardization (ISO)	International	International Cartographic Assoc. (ICA) International Hydrographic Bureau (IHB) Open GIS Consortium (OGC)

Figure 2

The GIS Standards / Spatial Data Infrastructures

The GIS standards infrastructure, a specific subset of the global standards infrastructure, provides an institutional structure and process for coordinating and integrating the development of GIS standards. The levels of the GIS standards infrastructure correspond with the global spatial data infrastructure. This correspondence in levels reflects common coverage in organizational jurisdiction and applicability. At the government and national levels, there will be some variation depending on the political and cultural composition of a particular country. The term regional, in the context of the GIS standards infrastructure and the global spatial data infrastructure, applies to a grouping of countries. Regional can also be applied to a grouping of cities, counties, and provinces - depending on the country and its composition. By example, the following is a description of the GIS standards infrastructure primarily from the perspective of the United States of America. (Figure 2)

National Level

For the United States of America, standardization efforts occur at the state government, federal government, national, and international levels - standardization at the local level is incorporated under the state level. (Figure 3) At each level of the GIS standards infrastructure, there can be two types of organizations developing standards: formal standards bodies and user/industry organizations.

Within the United States, standards efforts at the city and county levels form tiers under the state level. These efforts are either formal or user/industry based. States in the US are generally influenced by the activities of other states, associations of states, and primarily, the federal government.

At the U.S. federal government level, the National Institute of Standards and Technology (NIST) promulgates standards for organizations within the federal government. NIST is a formal standards body. The Federal Geographic Data Committee (FGDC) is the primary user group at the federal government level. The FGDC is composed of federal organizations which have a primary interest and activities involving spatial data. In 1994, FGDC was given a mandate to initiate the development of spatial data standards. FGDC has approved the Spatial Data Transfer Standard (SDTS) and its Topological Vector Profile (TVP) and developed the Metadata Standard. FGDC has been quite active and as of September 1996, two standards have completed the public review stage, four standards are either in preparation or out for public review, ten standards in draft, and five proposed standards. (Appendix A)

At the U.S. national level, this consists of the federal and state governments, public, private, academic and professional communities. The formal standards body at this level is the American National Standards Institute (ANSI) accredited X3L1, GIS technical committee. At the national level, user/industry groups include the Open GIS Consortium (OGC), National States Geographic Information Council (NSGIC), and also the Federal Geographic Data Committee. NSGIC is a council composed of the state GIS coordinator or equivalent for almost all the states in the US. The OGC is a consortium of vendors, integrators, researchers, government agencies, data suppliers, and users. The objective of OGC is to share spatial data and geoprocessing functionality through middleware (software) within a distributed computing environment. The OGC is currently developing the Open Geodata Interoperability Specification (OGIS). When completed, it will be submitted to the formal standards environment for approval as a standard. All participants at the national level contribute to the formal process of GIS standardization through X3L1. X3L1 also serves as the US Technical Advisory Group (TAG) to the recently formed International Organization for Standardization (ISO) Technical Committee 211, Geographic Information/Geomatics.

GIS Standards/Spatia Data Infrastructure

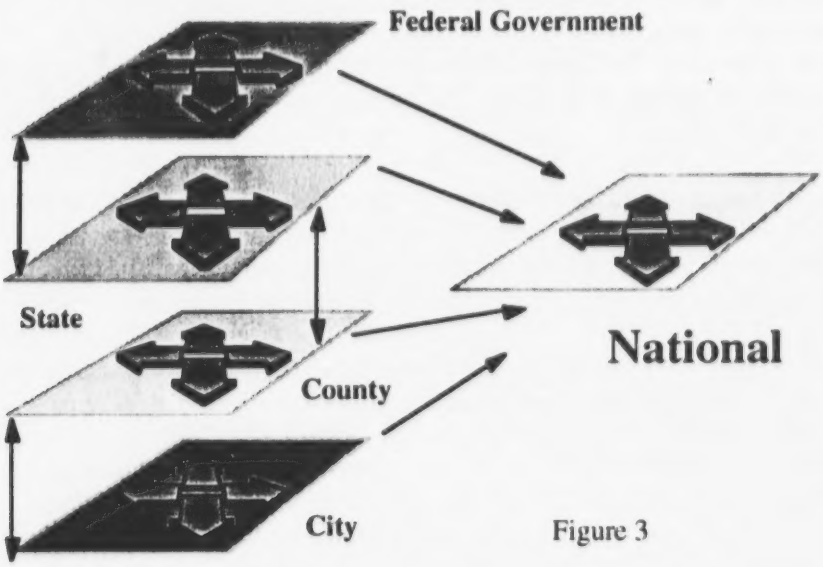


Figure 3

A national spatial data infrastructure formalizes the structure and process for organizing, using and sharing spatial data common to a broad spectrum of applications and users within a country. The concept of a spatial data infrastructure is not new. The need was recognized several years ago. In 1990, the Federal Geographic Data Committee (FGDC) in the United States of America began such an initiative. This effort received substantial visibility when President Clinton issued Executive Order 12906, April 11, 1994 to formally establish the National Spatial Data Infrastructures (NSDI) and the Secretary of the Interior, a member of the President's Cabinet, personally chaired the FGDC. Other countries such a Canada, the United Kingdom, Australia, Japan and Korea, have also established their own NSDI during the past two years. In Chile, the First International Symposium on Spatial Databases of Immediate Access, Oriented to Multi-Users and Multiple Applications was held from October 29-31, 1996 in Valparaiso, Chile. The third day of this meeting was devoted to exploring proposals and possibilities in achieving a global spatial data infrastructure. The resulting proposal is one supporting the development of a national spatial data infrastructure. A robust national level within the GIS standards infrastructure enhances the integration of spatial data across a national spatial data infrastructure while providing the integration paths to a regional and/or global spatial data infrastructure.

GIS Standards/Spatia Data Infrastructure

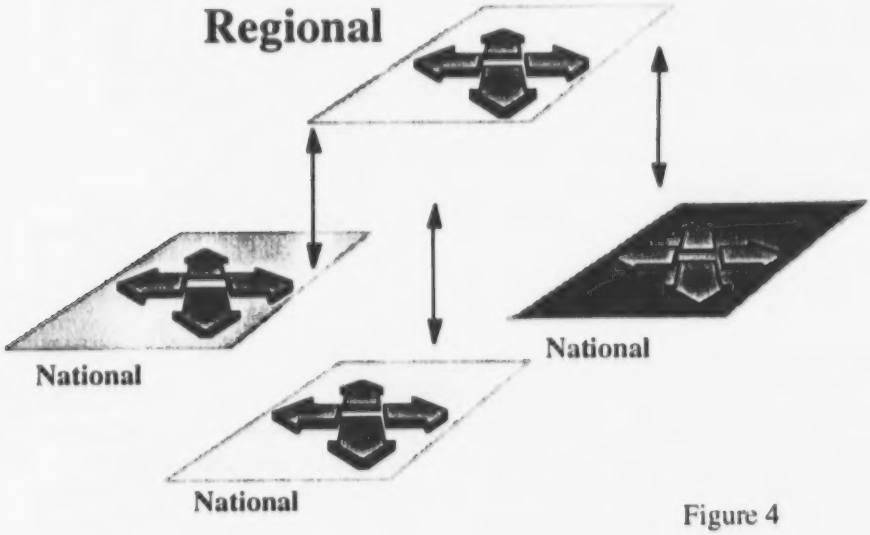


Figure 4

Regional Level

Although the United States does not include a regional level (group of countries), the regional level for European and the Asia and Pacific countries is quite significant. Thus, depending on the region of the world, levels for the GIS standards infrastructure will vary accordingly. (Figure 4)

In terms of a regional level within the GIS standards infrastructure, Europe has a formal regional standardization body. The European Committee for Standardization (CEN) is very active with two technical committees having direct relevance to GIS standards, CEN/TC 278, Road Informatics and CEN/287, Geographic Information. The major user group is EUROGI, which serves as the umbrella organization for 16 national geographic information associations, six pan European organizations, and includes a number of observers. The European community, under the leadership of the European Umbrella Organization for Geographic Information (EUROGI), established the European Geographic Information Infrastructure (EGII), while the Permanent Committee on GIS Infrastructure for Asia and the Pacific was formed recently. Although the Asia/Pacific regional standards body is not currently engaged in GIS standards, this may not be necessary. The Permanent Committee on GIS Infrastructure for Asia and the Pacific, the primary user group for this region, may adopt GIS standards directly from ISO/TC 211. The directors of national surveying and mapping organizations for over 55 countries were invited to attend the meeting in Sydney, Australia from September 29 - October 4, 1996. The Permanent Committee was formed as a result of a resolution passed at the Thirteenth United Nations

Cartographic Conference for Asia and the Pacific in Beijing, China in May 1994. The Permanent Committee has made progress in approving the Statutes and Rules of Procedure and the organization of the following working groups and their work plans:

WG1 Geographical Information Infrastructure and Institutional Framework
WG2 Issues relating to Cadastral Infrastructure
WG3 Regional Geodetic Networks
WG4 Legislation and administrative arrangements for the acquisition and sharing of spatial data.

Both the European and Asia / Pacific regional spatial data infrastructures are converging in their consensus that the work of ISO/TC 211 may provide the GIS standards to enable the global spatial data infrastructure. Also, there was an overall agreement on the need to cooperate and coordinate on issues requiring further study and resolution. At these international meetings, the global sharing of spatial data was deemed essential - providing international benefits which contribute to improving the quality of life and preservation of the global environment. The focus in the European region was data sharing, while in the Asia and the Pacific region, it was technology transfer.

International Level

At the international level, ISO is the formal standards body. There are more than 100 member countries in ISO. Each country has a national standards organization which represents them in ISO. Depending on interest in a technical committee, each national standards body designates a Technical Advisory Group (TAG) to represent the national body within the technical committee. Each country has only one vote. Liaison members to an ISO technical committee may receive technical documents and participate at meetings, however, liaison members may not vote. National body members with an observer status may vote in letter ballots.

User/applications groups at the international level include: International Cartographic Association (ICA), International Hydrographic Bureau, and the International Society for Photogrammetry and Remote Sensing (ISPRS). Because OGC now has memberships from various countries, it can also be considered as an international user organization.

In April, 1994, ISO/TC 211, Geographic Information/Geomatics was established and held its first plenary meeting during November, 1994 in Oslo, Norway. There are twenty-four members and thirteen observing members. From the user perspective, ISO/TC 211 has nine Class A liaisons with international organizations, as well as seven other ISO technical committees.

Many of the GIS standards required for spatial data infrastructure, at all levels, are currently being developed by this committee.

The Secretariat of ISO/TC 211 is Norway and the Chairman is Mr. Olaf Ostensen. The current program of work includes twenty work items which will become standards. The ISO standard identified for this work is ISO 15046, parts 1-20 with completion slated for 1998. (Appendix B) While the program of work for ISO/TC 211 is substantial and broad, the real measure of success will be whether or not these standards can function as an integrated set of standards. The success of the global spatial data infrastructure is directly dependent upon the GIS standards infrastructure and its international component, ISO/TC 211.

Recently, EUROGI and other leading geographic organizations such as the Atlantic Research Institute, Institute for Land Information (ILI), Deutscher Dachverband fur Geoinformation, Open GIS Consortium, FGDC, and Commission 3, Federation Internationales des Geometres (FIG) under the sponsorship of the European Commissioner, Mr. Martin Bangemann, held a meeting from September 4-6, 1996 in Bonn, Germany to initiate a dialogue on the Emerging Global Spatial Data Infrastructure. There was consensus on the need for a common vision, vocabulary, and an international forum to coordinate such efforts. The meeting was attended by representatives from twenty countries primarily from the European region. (Figure 5)

GIS Standards/Spatia Data Infrastructure

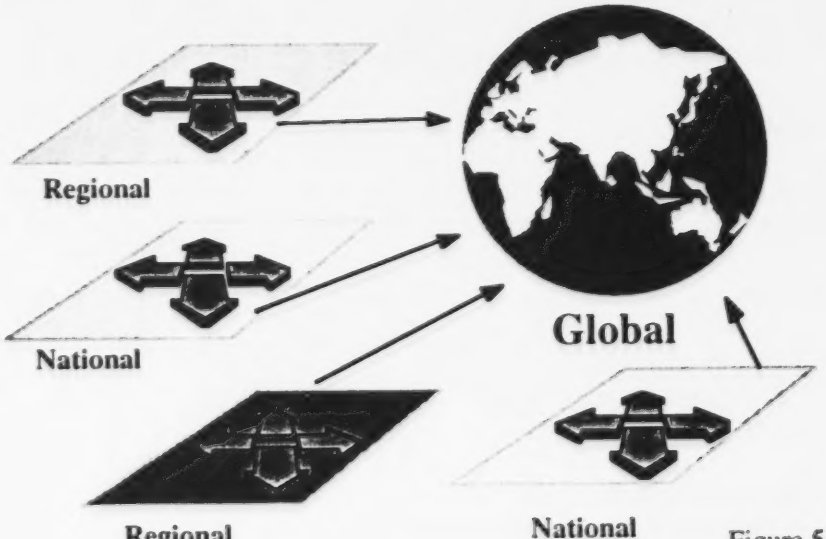


Figure 5

Conclusion

As envisioned, the global spatial data infrastructure has four components to enable its realization: technology, standards, policy, and institutional framework. With standards as a major component, the GIS standards infrastructure is established with a well-defined structure and process. Incorporating the GIS standards infrastructure within the global spatial data infrastructure provides much of the needed integration for spatial data.

Standards for the global spatial data infrastructure represents a rare opportunity to truly make a difference - globally. Many developing countries not currently participating in ISO work may now take an active role. This is because standards and the participation in developing standards is a mechanism for technology transfer. GIS technology is also fundamental for much of the infrastructure development projects in developing regions of the world. Successful regional integration of enabling information technologies such as GIS technology will depend, in no small part, on availability and acceptance of standards.

Appendix A -

Status of U.S. Federal Geographic Data Committee (FGDC) Standards
September, 1996

Approved

Spatial Data Transfer Standard (SDTS)
Spatial Data Transfer Standard (TVP) Topological Vector Profile
Content Standard for Digital Geospatial Metadata

Completed Public Review

Cadastral Data Content Standard
Classification of Wetlands and Deep Water Habitats

Out for Public Review

Vegetation Classification Standard

In preparation for Public Review

Soils Geographic Data Standard
Geodetic Control Networks Accuracy Standard

National Spatial Data Accuracy Standard

Standards in Draft

Standards for Digital Orthoimagery
Standards for Digital Elevation Data
Transportation Network Profile for SDTS
Specification for Encoding a Linear Referencing System
Point Profile for SDTS
Transportation Spatial Data Dictionary
River Reach Coding Standards
Metadata Profile for Cultural and Demographic Data
Geospatial Positioning Accuracy Standards
Digital Geospatial Metadata Standards for Geodetic Data

Proposed Standards

Cartographic and Digital Standards for Geologic Data
Utilities Data Content Standard
Geospatial Environmental Hazards Standard
Facility Identification Data Standard
CADD Profile for SDTS

Appendix B -

Overview of ISO/TC 211, Geographic Information / Geomatics

Scope:

Standardization in the field of digital geographic information. This work aims to establish a structured set of standards for information concerning objects or phenomena that are directly or indirectly associated with a location relative to the Earth. These standards may specify, for geographic information, methods, tools and services for data management (including definition and description), acquiring, processing, analyzing, accessing, presenting and transferring such data in digital/electronic form between different users, systems and locations. This work shall link to appropriate standards for information technology and data where possible, and provide a framework for the development of sector-specific applications using geographic data.

Members:

P - Members (24)

Australia
Austria
Republic of Korea
Morocco

Canada	The Netherlands
China	New Zealand
Czech Republic	Norway
Finland	The Russian Federation
France	South Africa
Germany	Spain
Iran	Sweden
Italy	Turkey
Jamaica	United Kingdom
Japan	United States of America

Observers:

O - Members (13)

Belgium	Pakistan
Denmark	Poland
Hong Kong	Portugal
Hungary	Switzerland
Iceland	Ukraine
India	"Yugoslavia" *
Malaysia	

* "Serbia and Montenegro have asserted the formation of a joint independent state, but this entity has not been formally recognized as a state by the United States. The United States view is that the Socialist Federal Republic of Yugoslavia (SFRY) has dissolved and that none of the successor republics represents its continuation.

Class A Liaisons (9):

Digital Geographic Information Working Group (DGIWG)
European Petroleum Survey Group (EPSG)
International Association of Geodesy (IAG)
International Cartographic Association (ICA)
International Federation of Surveyors (FIG)
International Hydrographic Bureau (IHB)
International Society of Photogrammetry and Remote Sensing (ISPRS)
Open GIS Consortium (OGC)
United Nations Economic Commission for Europe (UNECE)

Internal Liaison (7):

ISO/TC 46/WG2	Information and Documentation Coding of country names and related entities
ISO/TC 82	Mining
ISO/TC 184/SC4	Industrial Automation Systems and Integration

ISO/TC 184/SC4	Industrial Automation Systems and Integration
ISO/TC 204	Transport Information and Control Systems
ISO/IEC/JTC 1/SC21/WG 3	OSI, Data Management and ODP
ISO/IEC/JTC 1/SC 30	Open EDI
ISO/IEC/JTC 1/SWG GII	Global Information Infrastructure

ISO/TC 211 work groups and work items:

WG 1, Framework and Reference Model - Convenor, United States of America

Reference Model
Overview
Conceptual Schema Language
Terminology
Conformance and Testing

WG 2, Geospatial Data Models and Spatial Operators - Convenor, Australia

Spatial Subschema
Temporal Subschema
Rules for Applications Schema
Spatial Operators

WG 3, Geospatial Data Administration - Convenor, United Kingdom

Cataloguing
Geodetic Reference Systems
Indirect Reference Systems
Quality
Quality Evaluation Procedures
Metadata

WG 4, Geospatial Services - Convenor, Norway

Positioning Services
Portrayal of Geographic Information
Encoding
Services

WG 5, Profiles and Functional Standards - Convenor, Canada

Profiles

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REPORTS ON THE CONTRIBUTION OF SURVEYING, MAPPING AND CHARTING TO SUPPORT THE IMPLEMENTATION OF AGENDA 21: SAFETY OF MARITIME AND AIR NAVIGATION, INCLUDING HYDROGRAPHIC SURVEYS AND NAUTICAL CHARTING

The Digital Nautical Chart-A Multi-Use Data Base**

(Submitted by the United States of America)

* E/CONF.89/1.

** Prepared by Captain J. E. Ayres, USN, National Imagery and Mapping Agency.

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UNITED NATIONS
ECONOMIC AND SOCIAL COUNCIL

ECONOMIC COMMISSION FOR ASIA

Fourteenth United Nations Regional
Cartographic Conference for Asia and the Pacific

Bangkok, Thailand
3-7 February 1997

THE DIGITAL NAUTICAL CHART- A MULTI-USE DATA BASE

Submitted by Captain J.E. Ayres, USN (Retired)
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Fairfax, Virginia 22031-2137
USA

The National Imagery and Mapping Agency (NIMA) is an agency of the Department of Defense(DoD), primarily charged to supply the accurate imagery, imagery intelligence, and global geospatial information required by the United States Army, Navy, Air Force, and Coast Guard. In addition, we are required by law to make available to the civil sector those of our products which enhance the safety of marine navigation. Our Defense mission has required us to provide products in a variety of paper and digital formats, often duplicating the information content to meet unique format requirements of the various systems being served. This situation is rapidly improving as we pursue the DoD goal of fully interoperable systems within and between the Services. We have standardized our raster and compressed raster data formats, and especially we have settled on a standard vector format for a wide variety of products.

That vector standard is called Vector Product Format, or VPF, and it is our implementation of the international Digest-C standard format adopted by NATO and some National Governments. Among our current or planned VPF outputs are a V-Map series of digital multipurpose data bases at scales from 1:1,000,000 to 1:15,000, littoral warfare data bases encompassing a region which could extend from 200 miles at sea to 60 miles inland, special submarine navigation products, and the navigational data bases which will

replace paper nautical charts in the paperless ships of tomorrow's Navy. It is these navigational data bases which are the subject of this paper, for they hold the potential of serving coastal planning, environmental protection, transportation monitoring, and other civil efforts as well as safe navigation.

VPF is a relational data format, with data presented as topologically structured thematic layers. VPF and other formats in the DIGEST suite of standards rely on a Feature and Attribute Coding Catalog, the robust content of which supports nautical, aeronautical and topographic products alike. Because VPF is a relational data format, it is ideal for use in geographic information systems(GIS), where VPF data bases serve as versatile backdrops for the addition of purpose-specific information layers generated by the user. This can be illustrated by a discussion of our primary nautical chart product,the nautical navigational data base which we call the Digital Nautical Chart, or DNC.

The DNC is not only a comprehensive chart data base for ship navigation, it also is a component of other complex NIMA digital products such as the one for littoral warfare, and is designed to be integrated in combat systems with other VPF products. One way to do this integration, which avoids both translation loss and display confusion, is to have the combat system exploit the data directly in its VPF format. This approach is being taken by Navy and is expected to be implemented in some civil GIS display equipments. This does not rule out translation into another format for data exploitation, since all VPF data bases should translate the same way, but it does give a useful option.

I am assuming that enough has been published on electronic charts in recent years to ensure that you all are familiar with the subject. I'll therefore keep the explanation of the DNC brief. With the exception of its format, the DNC has been developed to satisfy the standards set forth by the International Maritime Organization(IMO) and the International Hydrographic Organization (IHO) for the data bases to be used in their Electronic Chart Display and Information System(ECDIS) equipment. ECDIS is a very high-end replacement for the conventional paper chart to be used by the civil mariner. The IHO specifies a data format called S57 for delivery of data to an ECDIS. However, unlike VPF which is both a transfer and an operating format, S57 is a transfer format only--data cannot be held in it for direct exploitation within an ECDIS system. DNCs in VPF contain the same data content and functionality as their S57 counterparts. The data layers contained in the DNC as a seamless data base are shown in Figure 1.

As can be seen from Figure 1, manyof the themes layered are essential to those who plan or monitor coastal zone activities. Although such things as cultural landmarks, land cover, and relief may have sparse coverage in the DNC because only material relevant to safety of navigation is included, the coding catalog includes features and attributes to facilitate input of a broad

range of user information under the categories, and standardized symbology for these additions exists for use on other NIMA products.The data basic to exploitation for coastal zone purposes, such as shoreline, islands, depths, bridges and so on are there, and are to the best accuracy available to us.

Our statutory commitment to the civil mariner is met through release for public sale of products for defense which enhance safety of navigation, and will be met by release of the DNC. This will make the DNC available not only to the mariner, of course, but also to those who require data bases of the geographic areas covered for other purposes.

Our production of DNCs is proceeding. We are dividing the world into 29 regions for CD-ROM purposes, as shown in Figure 2, and intend to digitize over 3700 charts to establish the full data base. Data bases are constructed by libraries which represent the scale ranges associated with general, coastal, approach and harbor charts, plus a browse library for orientation on DNC content. Tile size varies by library, as noted in Figure 1. Our NIMA production priorities place emphasis on U.S. ports and approaches, and Navy home ports overseas, in order to allow early practical training of Navy personnel as soon as their navigation display systems are installed aboard ship. We are also giving priority to support of special Navy projects as they arise. In addition,we are now in, or arranging, coproduction of VPF products with other nations, which will expedite the availability of the data bases. We should achieve worldwide DNC coverage by 1999. All DNC will be on WGS 84 datum, and show depths in meters.

We have a VPF updating method in an advanced state of development, and based on it will implement a DNC telecommunications based update service for Navy. Because of the lower data rates used in communications by much of the civil merchant marine, we still must consider what update service will be adequate for that sector. While updating is vital for navigation applications of the DNC, it probably is a minor consideration for most GIS purposes. NIMA is also developing what we have termed Full Utility Navigation Demonstration, or FUND, software which we require to help familiarize our customers with the DNC, but which should actually exploit the DNC in operating systems to an estimated 95 percent or more of the capabilities for safe navigation, and be of use in GIS exploitation of the data base. The FUND software is currently UNIX based, but shortly will be available also in Windows NT for PC application.

The DNC data base results from the digitization of charts from the NIMA portfolio. Many of these charts are based on data gleaned from foreign survey operations. The free use of foreign data in chartmaking has long been an established practice by many nations, as it was recognized that all benefited by increased availability of reliable charts. In recent years, however, the safety

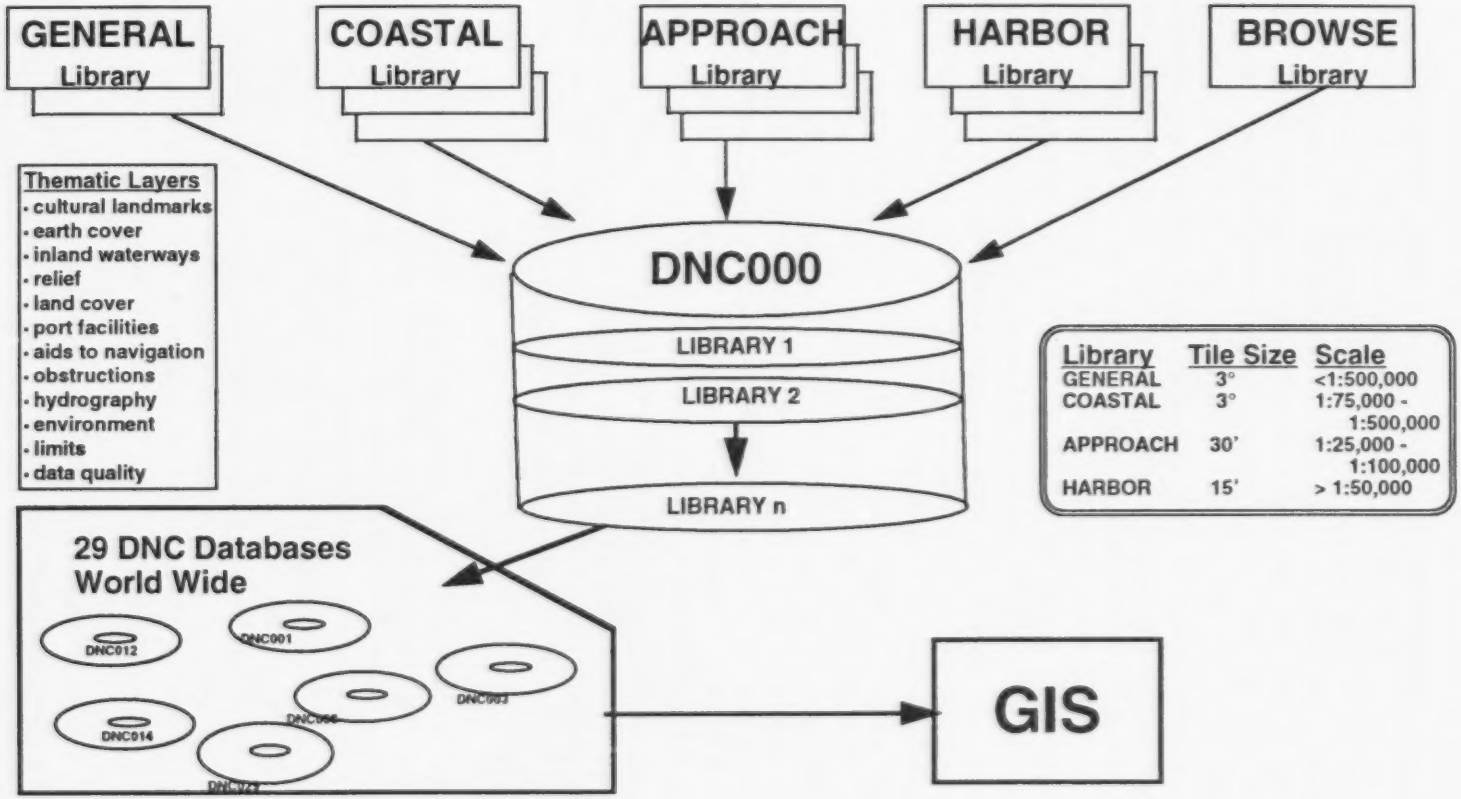
of navigation has taken a poor second place to the bottom line in the revenue ledger of several nations, and claims of copyright and intellectual property rights have been put forward in an attempt to obtain revenue for data used. While it has been the NIMA position that natural facts, whether the height of Mount Everest or the depth of the sea off Gibraltar, are not subject to copyright or intellectual property rights consideration, we do recognize that major resources and considerable personal effort go into the collection of chart data. We wish to avoid agreements which require administrative overhead which would probably far exceed the amount of royalty payments involved in the public sale of our charts based on foreign data, and we would not recognize any constraint on the use of NIMA products for U.S. Government purposes. But in the spirit of cooperation we would consider agreements to make available to the country whose survey data was used in our charts the VPF database which covered that country's national waters and coasts, and the international waters of its region, software to facilitate updating if the software rights are held by NIMA, and our FUND software to manipulate the data. The recipient country's Hydrographic Authority could repackage and sell the data for GIS purposes such as coastal or environmental planning or, if they implemented an updating service, for navigation. We believe that such an approach could relieve a number of small Hydrographic Offices from the necessity to spend the substantial resources required to produce a vector data set such as is now called for by the IHO, as well as result in a positive cash flow for them from the sale of the repackaged DNC products. We know from our own experience, as well as that of others, that many Hydrographic Authorities desiring compensation do not want that compensation in the form of royalties, since such royalties could go directly to their nation's treasury rather than to their operating fund. We expect many to prefer to receive the VPF data.

We do not expect to place our DNCs of foreign waters on public sale before we have discussed an appropriate quid pro quo with the affected nations. However, we have made our DNCs of United States waters available for GIS and navigational aid purposes, and those same DNCs will replace the paper chart for navigational use as soon as an adequate civil sector updating service can be developed. DNC use in lieu of the paper chart by the civil mariner requires that the U.S. Coast Guard authorize the use of the data base, with approved equipment, in US waters. A similar authorization by the appropriate maritime regulatory authority would be required for such civil maritime use of digital chart displays in the waters of other nations.

We know that our VPF DNC data base is the only feasible option for our Navy. We believe that our approach to making our DNC data base and related software available to other nations is not only in their best interests but also that it furthers the safety of navigation and facilitates national planning. We are proud to be able to contribute to the common good.

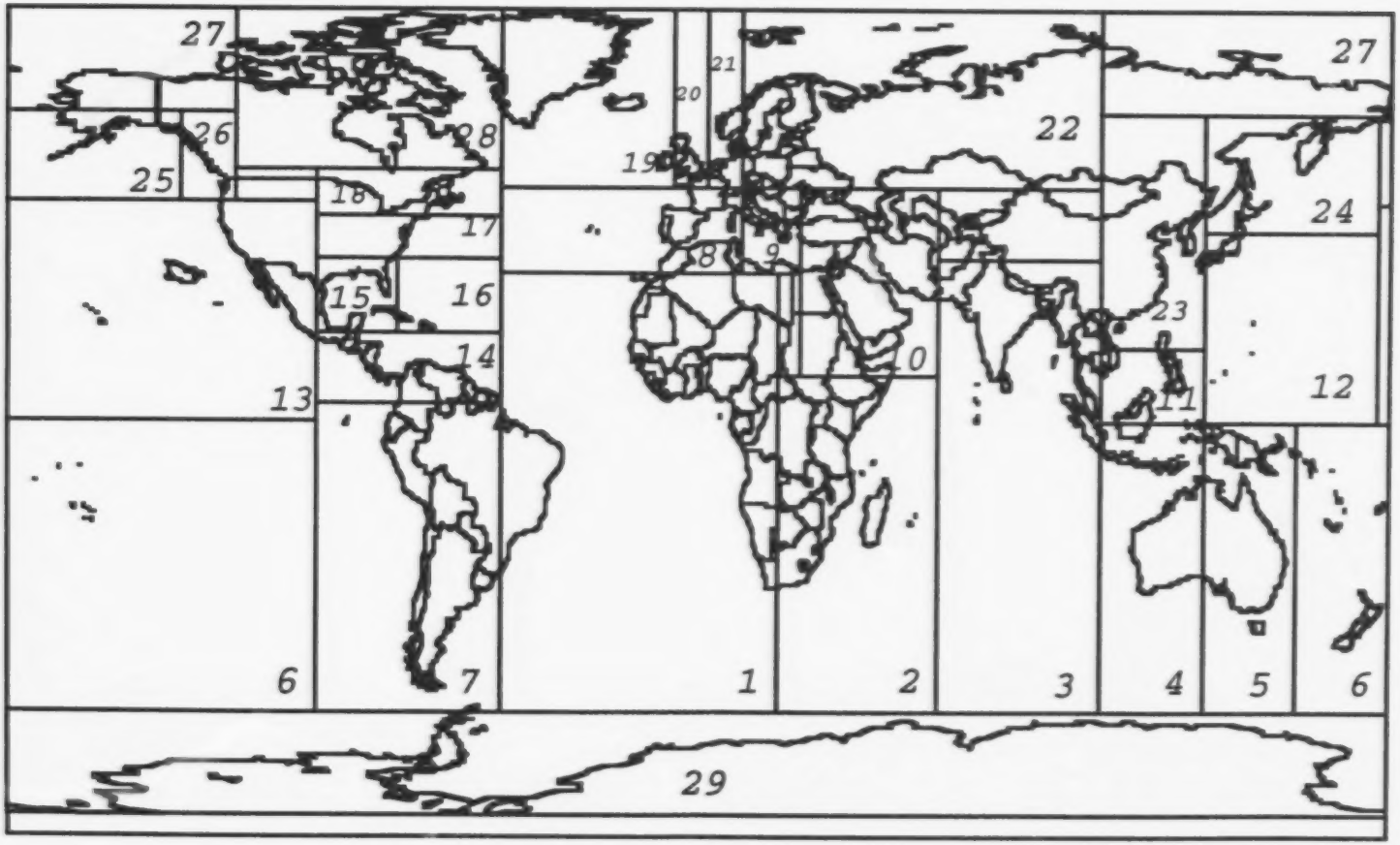
DNC Data Content

DNC DATABASE - Figure 1



DNC CD-ROM Footprint

Figure 2



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REPORTS ON THE CONTRIBUTION OF SURVEYING, MAPPING AND CHARTING TO SUPPORT THE IMPLEMENTATION OF AGENDA 21: OTHER APPLICATIONS OF SURVEYING AND MAPPING TO SUPPORT THE IMPLEMENTATION OF AGENDA 21

The U.S. National Spatial Data Infrastructure**

(Submitted by the United States of America)

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* E/CONF.89/1.

** Prepared by Barbara S. Poore, Federal Geographic Data Committee.

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THE U.S. NATIONAL SPATIAL DATA INFRASTRUCTURE

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INTRODUCTION

Over the past few decades such tools as satellite remote sensing equipment, global positioning systems, map digitizing and scanning equipment, image processing software, geographic information systems, and digital map printing systems, have allowed governmental and private sector organizations to collect, analyze, and manage electronic information related to geographic location in a way never possible before. As the technology has evolved, the value of spatial analysis has been increasingly recognized as an aid to understanding environmental and social issues that are often closely related to geographic location. These tools can integrate many different themes of data, and their usefulness has resulted in an expanded base of users.

As the user base has grown, so has the complexity of the environmental, economic and social questions being asked. The production of geographic data is burgeoning. Geographic data are now being produced by thousands of organizations in the public and private sectors. Even though many different data sets are being produced over many different geographic areas at many different levels of resolution, there are few organizations with the resources to produce and maintain all the data they need to take full advantage of these new technologies.

Since many organizations may produce and maintain geographic data about the same location, data might conceivably be shared between and among organizations, allowing organizations to direct their resources into problem solving rather than data collection. As part of a movement to streamline government operations and better manage resources, the concept of geographic data as a shared basic infrastructure to support complex decision making has lead to the development of the National Spatial Data Infrastructure (NSDI). The NSDI, as established by Executive Order in 1994, is defined as "the technology, policies, standards, and human resources necessary to acquire, process, store, distribute, and improve the utilization of geospatial data." (Executive Office of the President 1994)

THE CONCEPT OF THE NATIONAL SPATIAL DATA INFRASTRUCTURE

Historially organizations that used GIS developed a "stovepipe" approach to problem solving. Separate organizations, or even separate parts of the same

organization, would collect different themes of data using different combinations of software and hardware for unique applications. Information was seldom shared across organizational lines. It became increasingly clear that this approach was inefficient and did not take advantage of the integrating capabilities of GIS that allow many attributes and themes of data to be registered to one geographic location. Agencies began to realize the value of developing a more open approach in which data that are commonly used can be shared within an organization and exchanged with groups outside the organization. For example, a county planning department, a highway department, and a tax office may each develop and maintain separate street center-line data bases. A more efficient arrangement would allow one street file to be shared with among departments. This requires defining which of the three offices is responsible for updates and maintenance. Emphasis is placed on developing working relationships between and among the participants and developing standards that enable data sharing rather than on unique data collection.

This approach builds on the concept that geographic space can serve as a common denominator for problem solving. Sharing data can result in efficiencies in data development and responds to current organizational changes such as corporate "downsizing," the devolution of authority towards flatter organizational structures, and an interest in partnerships. Such an approach can create the multifaceted collections of knowledge needed to cooperatively tackle complex issues such as regional transportation planning or community sustainability.

The Federal Government, to encourage data sharing partnerships, made NSDI a major part of its effort to improve the way in which services are delivered to its citizens. A September 1993 report stated that "[I]n partnership with state and local governments and private companies we will create a National Spatial Data Infrastructure." (Gore 1993) Implementation of the NSDI was effected through the issuance of Executive Order 12906 in April 1994. This order directs Federal agencies and the Federal Geographic Data Committee (FGDC), an interagency coordinating body, to provide federal leadership in the development of the NSDI.

ACTIVITIES TO DEVELOP THE NSDI

Initial activities to implement the NSDI concentrated on standards development, data sharing through clearinghouses, and shared production responsibilities for certain basic framework themes of data. These priorities were established through a series of public meetings of individuals from the public and private sectors and are outlined in the "1994 Plan for the National Spatial Data Infrastructure" (Federal Geographic Data Committee, 1994a) and in the Executive Order.

Standards

Data sharing requires standards. Standards are most effective when they voluntarily emerge from wide acceptance and use within a community. Any standards process must take into account not only technical issues, but institutional, economic and behavioral issues. Standards development can often be contentious. Within the

FGDC the Standards Working Group facilitates the overall process within which standards are developed by any of a dozen thematic subcommittees. Each subcommittee develops standards for data collection and content, data presentation, and data management for a particular theme of data such as transportation, vegetation, cadastral or soils. Standards undergo extensive nationwide public review and revision that encompasses comment and testing phases and solicits input from state and local government agencies, private sector firms, and professional societies. The process may be time consuming but it increases the likelihood that standards will be used throughout the community. To date, a metadata standard has been developed and adopted in 1994; cadastral standards and a wetlands classification standard have completed national review; and several standards are ready for national review. These include a cultural and demographic profile for metadata, a transportation profile for data transfer, a vegetation classification, and an accuracy standard for spatial data collection and representation.

Clearinghouse

The National Geospatial Data Clearinghouse links people seeking data with data producers. The clearinghouse is decentralized; that is data are maintained locally while information about where data can be obtained is shared through electronic networks. Potentially millions of data holdings in many different geographic locations will be cataloged and accessed through the clearinghouse.

Three elements are necessary to operate a distributed clearinghouse. Metadata, or "data about data" provides information in a data transfer and is essential to the clearinghouse concept because it serves as a catalog entry for data when made accessible on the Internet. The Content Standards for Digital Geospatial Metadata (Federal Geographic Data Committee, 1994b) establishes a consistent means to describe the quality and characteristics of spatial data. The Executive Order mandated that all Federal agencies use the standard to document new spatial data sets created after January 1995. Data producers from other levels of government, as well as the private sector, are being encouraged to use the standard to describe their data.

The second required element of the clearinghouse is the Internet. As the "network of networks" linking millions of people globally, it provides users with the ability to retrieve metadata descriptions of data sets held by data producers. Some data producers may also put the data online for downloading. Federal agencies and other organizations are being encouraged to use the Internet to provide access to metadata descriptions of their data holdings.

The third requirement in implementing the clearinghouse is the use of software tools for searching and querying data on the network. "Browsers" allow users to access "home pages" on the World-Wide Web, a graphical protocol for displaying information on the Internet by means of hypertext links. Many organizations are sharing both metadata descriptions and data by allowing users to browse their World-Wide Web sites. The FGDC is supporting the development and enhancement of searching software and the refinement of a search engine based on

ISO 10163 (ANSI Z39.50) an international standard maintained by the library community, that specifies how an information search is expressed. This standard will allow for structured spatial searching of many different servers on the Internet for metadata. Current research is also underway to develop intuitive graphical map-based interfaces for searching and displaying the geographic locations and other characteristics of metadata.

Most Federal agencies and many state and local governments are currently disseminating data through sites on the Internet. Many thousands of files a month are being accessed in this manner, saving the cost of mailing maps or computer tapes. The U.S. Fish and Wildlife Service reported that in the first month of operation, approximately 29,000 digital maps from the National Wetlands Inventory were retrieved. The U.S. Geological shared 40,000 digital files with its customers during the first three months it had established an Internet presence. (Federal Geographic Data Committee, 1994c)

Framework

This activity is attempting to develop a framework of commonly-used themes of data based on shared responsibility for data creation and maintenance. These themes include digital orthoimagery, geodetic control, elevation, transportation, hydrography, governmental boundaries, and cadastral or ownership information. The framework will provide a current base on which to collect, register, or integrate other data sets for analysis. Although framework data often will only be used to support other applications, many organizations spend time and money digitizing or seeking these data sets. A common approach to building and maintaining these data sets could free an organization's resources for more pressing applications.

A Framework Working Group was formed by the FGDC in 1994 to study how to prototype the framework activity. This group consisted of representatives of Federal, state, and local government agencies. They proposed linking various existing data collection activities over specific geographic areas, recognizing that, in most instances, local governments are collecting the highest resolution data and have the most at stake in keeping their data current (Federal Geographic Data Committee 1995). Local organizations thus will play a critical role in the development and maintenance of framework data. The framework approach will allow state and Federal agencies, through collaboration with local governments, to obtain data that is more current and accurate than they would be able to create themselves.

A series of pilot studies is underway to test the assumptions of the group's report. These studies will help identify institutional issues, develop standards, possible funding initiatives, and operational guidelines for developing framework data.

ENCOURAGING PARTICIPATION IN THE NSDI

Promoting the idea of data sharing and collaboration among a diverse and widely spread set of organizations has been one of the FGDC's primary challenges. Political support from the President's Office of Management and Budget and the willingness of the Secretary of the Interior to chair the FGDC have provided a mandate and political visibility to the effort. The Secretary's involvement, in particular, has encouraged other Federal agencies to commit resources at high political levels, and has persuaded many state and local governments to elevate local needs for spatial data production and coordination. National attention has also hastened the use of standards and improved data accessibility.

The FGDC has structured its activities to allow participation by non-Federal organizations in ongoing development of the NSDI. Some of the initiatives to broaden participation are:

Establishing coordinating groups with interest in a particular geographic area. Many states have geographic information councils that cross institutional and organizational boundaries because of their concern for solving local problems. Such councils can be important allies in the development of standards and for outreach on data sharing issues. The FGDC has a formal program to recognize these councils as partners in the development of the NSDI. Twelve councils have been recognized thus far and many have participated in meetings with the FGDC.

The FGDC established a Competitive Cooperative Agreements Program to encourage participation and experimentation in the development of the NSDI. These agreements are funded through an annual competitive process. Participants support collaborative activities on metadata implementation, data clearinghouse development, framework data, standards development and implementation, and other issues. A total of 62 cooperators from state and local governments, non-profit organizations, academic institutions, and private industry have been funded in the three years since this program began.

The FGDC conducts numerous training courses, workshops and presentations about its activities at national, state, regional and user group conferences. The FGDC and its various subcommittees publish a newsletter and several technical reports each year. These can be accessed electronically from the FGDC home page on the World-Wide Web <http://www.fgdc.gov>

FUTURE EVOLUTION OF THE NSDI

The NSDI is constantly evolving as telecommunications and GIS technologies change. Thus, predicting the future is difficult. Institutional, social, and economic

issues will play a large role in future directions. Some of the questions that will certainly impact the future of the NSDI are listed below:

Economic and institutional:

What are the implications of cost-recovery policies on the evolution of the NSDI, and how will the imposition of such fees impact the availability and quality of spatial data?

Should copyright be applied to spatial data?

What should be the data collection and maintenance roles of federal, state, and local agencies over a given piece of geography, and how do these relate to private sector initiatives?

What incentives will promote interagency coordination; what are the constraints?

What mechanism, if any, is required to oversee the NSDI?

Standards:

What standards will promote data sharing?

How are standards best created, by the federal government; the private sector?

Who should be responsible for maintaining standards?

What mechanisms or incentives will encourage the use of standards?

Is the concept of a "certified" data set useful, and, if so, who would certify?

Technical issues

How can different data sets from different computers be used across a distributed network?

What is the best way to promote interoperability? Through transfer standards? Data structure specifications? And what roles and incentives are there for the private sector?

How can multiresolution data sets collected by different organizations best be integrated and used?

Who defines features and on what basis?

What is the best way to represent metadata to the end user?

CONCLUSION

Efforts so far to develop the NSDI have focused on very specific problems such as: Who has what data? How can data sets be accessed? Are these data suitable for my application? Future efforts will depend on the community's ability to agree on many institutional, policy, economic and technical issues. These challenges will only be overcome and the NSDI developed through the creation of partnerships, placing responsibility for data creation at local levels, and collaborating to resolve issues.

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REPORTS ON THE CONTRIBUTION OF SURVEYING, MAPPING AND CHARTING TO SUPPORT THE IMPLEMENTATION OF AGENDA 21: OTHER APPLICATIONS OF SURVEYING AND MAPPING TO SUPPORT THE IMPLEMENTATION OF AGENDA 21

The Vector Product Format, An Overview**

(Submitted by the United States of America)

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** Prepared by David M. Danko, United States National Imagery and Mapping Agency Standards and Interoperability Division.

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THE VECTOR PRODUCT FORMAT, AN OVERVIEW

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INTRODUCTION

The National Imagery and Mapping Agency is chartered with providing products for the US Military, Defense Agencies, and maritime customers. Increasingly these products are being produced in digital form. NIMA provides digital geospatial products primarily in three formats: Vector Product Format (VPF), Raster Product Format (RPF), and Text Product Format (TPF). Vector products account for the largest growth in the demand for digital data. NIMA produces a wide range of products which incorporate the VPF structure. The use of VPF for the distribution and direct application of geospatial information continues to expand.

BACKGROUND

Unlike many other government agencies which collect geographic information for internal use within their own organization, NIMA collects and furnishes geographic information, cartographic data, geodetic information, and navigation information to fulfill customer requirements. US Federal, state, and local agencies collect and use geospatial information for use in forest, land, water, and energy resource management, as well as for public works, urban planning, and understanding population trends. Typically this information is provided to the public and the private sector as a low-cost by-product to promote growth, development, and recreation. The US Department of Defense chartered NIMA with the responsibility to provide mapping, charting, geodetic, and geospatial

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information for use by the Army, Navy, Marines, Air Force, and Intelligence agencies, as well as for maritime navigation world wide. These products are used in a wide variety of activities such as strategic, regional, and tactical planning, mission planning and rehearsal, modeling for system development and performance testing, cockpit moving map display, on-board navigation, and many other applications.

As a customer oriented organization, NIMA maintains an active requirements collection component dedicated to working with customers to understand the type and format of data they require, as well as determining the geographic areas of the world for which they will need information. This component, as well as research and development groups within NIMA, works with weapons and other systems developers to insure that as new military systems and practices are developed, NIMA will provide the data they require. Data formats and digital products are developed using an iterative prototype design process to insure that NIMA products meet customer needs, and provide data in a readily usable form.

Geographic information standards such as the Spatial Data Transfer Standard (SDTS, US Federal Information Processing Standards - FIPS 173) and NIMA's internal Mapping Charting Feature Data Exchange Standard (MC&GFDES) are examples of very robust standards designed purely for information exchange. MC&GFDES was developed for the exchange of data within a very large integrated production system. SDTS was developed to support the exchange of spatial data of any type between organizations using, in many cases, proprietary Geographic Information Systems. Data type/content can vary so broadly that it is impossible to write a general purpose translator designed to handle all SDTS possibilities. As a robust exchange standard SDTS is not designed to reduce the size of the data for ease of distribution, nor provide indices for rapid access, nor carry redundant or pre-computed data for ease of access and use. It was not intended to be used for the distribution of products. FIPS 173 Paragraph 8 (Applicability) states: "FIPS SDTS is not intended to facilitate product distribution of spatial data in a form designed for direct access by application software specific to a particular data structure, class of computer platform, or distribution media". Product standards such as RPF and VPF must support the use of application software that can access information regardless of variation in content. A product standard must efficiently store information to minimize the number of tapes or discs needed to distribute the data. It must incorporate indices providing users efficient access to information.

THE VPF STANDARD

The VPF standard defines the conceptual and physical data model on which all NIMA vector products are based. It uses a geo-relational model which is physically organized into five hierarchical levels: Database Level, Library Level, Coverage Level, Feature Level, and Primitive Level. The geospatial feature is the central concept of the VPF data model. Real world features are modeled by

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describing their location (where) and their properties (what). The Primitive Level carries the location information using four basic primitives: nodes, edges, faces, and text. These are implemented in five types of primitive tables: Node Tables, Edge Tables, Face Tables, Ring Tables (which link faces to edges), and Text Tables. These tables contain topologic relationships and coordinate data. Feature tables are used to describe the properties of a geospatial feature. Each record in a feature table identifies the feature, its attributes, and its primitive(s). Four types of feature/primitive relationships are possible: one-to-one, many-to-one, one-to-many, and many-to-many. Sets of features and primitives form coverages, which are grouped in libraries; a collection of libraries form a database.

VPF coverages group features by topologic relationships ranging from no explicit topology to full topologic relationships for all primitives. Varying degrees of integration are supported: When a product does not require relationships among data types, data can be stored in separate coverages; when full topology is required features may be combined into a single coverage. Complex features, groups of features collected together and handled as a single entity, may be modeled. Utilizing these concepts products may be designed as simple or as complex as necessary facilitating efficient storage and use.

Limitations caused by restrictions in computer memory or distribution media capacity require that large geospatial databases be divided into manageable units, or tiles. VPF supports tiling using a concept of organizing primitives by geographic units and provides inter-tile topology to maintain geographic features in a logically continuous manner across tile boundaries. To the user, the data appears as one seamless unit.

Some other features of the VPF which enhance the utility of geographic information are:

Self Describing Format - each VPF level has header tables that describe the information contained at that level and a description of the level below. Each VPF table has a header describing the table. This allows software developers to design utility software which can adapt to any VPF database regardless of product design.

On-line Data Dictionary - The VPF data dictionary allows the definition of features and attributes to be carried with the product to avoid misinterpretation by users. The VPF utilizes "Value Description Tables" that specify and describe the feature attributes used in each coverage. Users can employ this capability when adding their own data to the database. They can describe feature and attributes which have been developed solely for their own purposes. These can be defined in the database and passed on for all to use. This allows each coverage to be used by a wide range of users without prior knowledge of a

coding system - enhancing interoperability and insuring the data is interpreted correctly.

Data Quality - VPF provides the capability to carry data quality information at the Library, Coverage, and Feature Level. This information will help the user perform geographic analysis. It allows users to weigh a product's accuracy, currency, and completeness when performing analysis.

The VPF standard defines a general database structure and rules for how to model geospatial feature geometry, topology, and attribute information. It does not define what features, geometry, topology, and attributes are to be carried in a data set. Product Specifications are used to describe what is to be included in a data set using the rules defined by the VPF standard. They specify what type of geometry: x-y coordinates on a plane or latitude-longitude coordinates on an ellipsoid, whether these coordinates will be 2-dimensional or 3-dimensional; what level of topology; and what features and what attribution will be carried in a product. All within the limits defined by the VPF standard.

As a Military Standard, VPF documentation is available to the public through the Defense Printing Service Detachment Office. Previously known as MIL-STD 600006, the VPF military standard has been updated and the new version has been assigned MIL-STD 2407. The standard can be accessed through the NIMA Homepage on the INTERNET (http://www.nima.mil). The standard can also be ordered by writing to:

Defense Printing Service Detachment Office:
Standardization Document Order Desk
Building 4D
700 Robbins Ave.
Philadelphia, PA 19111-5094
USA

To understand each NIMA product, a product specification must be used along with the VPF standard. These military specifications describe an implementation of the VPF standard.

VPF DATA AVAILABILITY

A wide variety of geospatial information is available in VPF. Development of new products continue as NIMA customer's requirements and applications expand. Many of these product specifications are available through the NIMA homepage on the INTERNET (http://www.nima.mil).

Digital Chart of the World/VMap Level 0

The Digital Chart of the World (DCW‰) is a comprehensive 1:1,000,000 scale equivalent resolution basemap of the world. The database is contained on four compact disc read only memory (CD-ROM). The database contains more than 1,500 megabytes of vector data and is organized in 10 thematic layers. The data

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includes major road and rail networks, major hydrologic drainage systems, major utility networks (cross-country pipelines and communication lines), all major airports, elevation contours (1000 foot(ft), with 500 ft and 250 ft supplemental contours), coastlines, international boundaries and populated places. The DCW also includes an index of geographic names to aid in locating areas of interest. The DCW is designed to support geographic information system (GIS) applications.

Edition 2 of the DCW will be released December 1996 as VMAP0 and is undergoing several design changes incorporating it into the Vector Map (VMap) series of products. International boundary information will be updated incorporating the latest changes as approved by the US State Department. Vegetation information will be expanded to include all of North America. Global bathymetric information will be added in the form of depth contours. VMAP0, as with all NIMA vector products, uses the Feature Attribute Coding Catalog (FACC) which is Part 4 of the Digital Geographic Information Exchange Standard for feature and attribute definition. The DCW is available to the general public (as will VMAP0) through the US Geological Survey, Earth Science Information Center (303-236-7477). The VMap0 is described in military specification MIL-D-89039.

World Vector Shoreline+

World Vector Shoreline (WVS+) is a product contained on a single CD-ROM which contains the world's shoreline at an equivalent resolution of 1:250,000. It also includes international boundaries including off-shore territorial boundaries and country names. Also included are representations of the world's shoreline at equivalent resolutions of 1:500,000, 1:1,000,000, 1:3,000,000, and 1:12,000,000. WVS will be available to the general public. Any vendor or publicly available software capable of reading VPF will be able to provide access to this database. The WVS+ is currently in production and will be available for public sale in December 1996.

Digital Nautical Chart

Digital Nautical Chart (DNC) products consist of VPF databases comprised of varying resolution libraries over a specified operational area. These libraries contain maritime significant geographic and navigation information typically found on standard nautical charts. Each library consists of 12 coverages: Cultural Landmarks, Earth Cover, Environment, Hydrography, Inland Waterways, Land Cover, Limits, Aids to Navigation, Obstructions, Port Facilities, Relief, and Data Quality. As an example a DNC may contain a General Library containing 1:1.2 million scale equivalent data; a Coastal Library containing 1:300,000 scale data; an Approach Library containing approximately 1:75,000 scale data; and a Harbor Library containing 1:20,000 scale equivalent information. When used by a navigator on-board ship, varying levels of detail are accessed by switching libraries as needed. Several DNCs have been completed and production is underway to cover the world's major ports by 1997. This will be produced by

digitizing 4000 nautical charts. The DNC may become available to the general public pending a legal review by the International Hydrographic Organization. Its design is described in military specification MIL-D-89023.

Vector Map

Vector Map (VMap) is a suite of products which contain basic topographic geospatial data at a variety of levels of resolution. All VMap products contain identical thematic coverages: Boundary, Data Quality, Elevation, Hydrography, Industry, Physiography, Populated Places, Transportation, Utilities, and Vegetation.

VMap Level 0 VMap Level 0 is identical to the DCW described above.

VMap Level 1 VMap Level 1 will consist of approximately 234 CD-ROMs covering the world with 1:250,000 scale equivalent information. World coverage is expected by 2000. VMap is fully described elsewhere in this publication. VMap Level 1 CD-ROMs covering areas which are not bound by international agreements restricting release will be made available to the general public. VMap Level 1 design is described in MIL-V-89033.

VMap Level 2 VMap Level 2 consists of information with a resolution equal to 1:50,000 to 1:100,000 scale data. Individual Level 2 products cover small geographic areas determined by the geographic operational requirements of NIMA's customers. Because of the sensitivity of this large scale information within many countries of the world, most Level 2 data will be restricted. The VMap Level 2 design is described in MIL-V-89032.

Urban VMap As the name implies UVMap products cover urban areas. These products provide information at resolutions ranging from 1:5,000 to 1:50,000. Although it uses the same 10 thematic coverages as other VMap products, feature content and the level of attribution are much richer. Like Level 2 many UVMap products will not be releasable to the general public. The UVMap product design is described in MIL-U-89036.

VPF APPLICATIONS

Listed below are several software applications packages which make use of VPF products. The products mentioned are just a sampling to provide an understanding of what is available. It is not a recommendation; any product which uses VPF and is not mentioned, was left out unintentionally.

VPFView Software

VPFView software is designed to access any database implemented in VPF. It allows the display of chosen combinations of features or themes for a user selected geographic area of interest. The software supports the display of VPF databases directly from CD-ROM, hard drive, or diskette without loading or

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converting the data. Display scale can be changed by zooming in or out. Portions of a database can be copied from removable storage media and saved on a computer's hard disk in VPF. Simple plots can be generated in postscript format. Source code is available to provide developers methods for importing the data into their proprietary systems. A users manual is included. Both VPFView DOS (Order Number PB94-501715GEI) and VPFView UNIX (Order Number PB94-501723) versions are available through the US National Technical Information Service (NTIS):

US Department of Commerce
NTIS
5286 Port Royal Road
Springfield, VA 22161
703-487-4650, FAX 703-321-8547

MC&G Utility Software Environment

MC&G Utility Software Environment (MUSE) Version 1.0 was developed by the NIMA to provide a sample suite of software exploiting NIMA digital products. MUSE operates in the Windows, Macintosh, and SUN MOTIF/Openlook environments. Full source code is provided to allow users to understand and develop their own versions of access software. MUSE provides routines to access and process a wide variety of NIMA products such as: Arc Digitized Raster Graphics (ADRG), Compressed ADRG (CADRG), Compressed Image Base (CIB), Digital Terrain Elevation Data (DTED) and a wide variety of VPF products. MUSE supports raster importing, vector importing, demonstration/briefing display tools, map fusion (overlaying raster data with vector information), standard NIMA datum transformations and coordinate conversions, line of sight computation and display, and perspective scene generation by fusing raster map data and elevation data. MUSE will extract data from VPF products; spatial extent is defined by entering geographic coordinates for the desired area; thematic selection is performed by allowing the users to define the coverages, libraries, and feature types to be accessed. VPF databases can be filtered by attribute by creating "thematic expressions". MUSE is distributed by NIMA on CD-ROM along with full documentation and sample data sets.

MIGRATION TO DIGEST

As a US Military Standard VPF is a controlled document, a stable design model, used for procurement and referenced by product specifications. The VPF geographic data model is based on the geographic model defined in the Digital Geographic Information Exchange Standard (DIGEST). VPF is equivalent to the implementation model defined in DIGEST Annex C, Vector Relational Format (VRF). DIGEST was developed by the Digital Geographic Information Working Group (DGIWG) a group of military map producers from 11 NATO nations. DIGEST, NATO Allied Geographic Publication 3 (AGeoP 3) has been ratified as NATO Standardization Agreement 7074 (STANAG 7074). In keeping with the

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DoD trend of moving away from the use of military standards, future producers and users implementing this vector relational model will drop the reference to the VPF Military Standard, and instead reference the internationally controlled DIGEST, STANAG 7074.

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REPORTS ON THE CONTRIBUTION OF SURVEYING, MAPPING AND CHARTING TO SUPPORT THE IMPLEMENTATION OF AGENDA 21: OTHER APPLICATIONS OF SURVEYING AND MAPPING TO SUPPORT THE IMPLEMENTATION OF AGENDA 21

Time-Invariant Bathymetry: A New Concept to Define and Survey it using GPS**

(Submitted by the United States of America)

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** Prepared by Muneendra Kumar, National Imagery and Mapping Agency.

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TIME-INVARIANT BATHYMETRY
A NEW CONCEPT TO DEFINE AND SURVEY IT

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Currently, there are hundreds of vertical datums, both for land and ocean areas, in use all over the world. As we live on land, the land datums always got the priority attention. Thus, to update them either datums, viz., the North American Datum (NAD) 1983, European Datum (ED) 1979, and EUREF 1989 have already been established or efforts to establish new datums, viz., SIRGAS for South America and KRF 1994 for Korea have been started.

Another important point is that no rigorous horizontal datum has ever been defined over ocean areas; the practice has been to always extrapolate the land datums to map the charts over oceans.
For nautical chart vertical datums, the situation is still more complicated by the lack of agreement on the definition(s) by different countries which in turn jeopardizes the safety of international navigation.

Further, the tidal surfaces used in the vertical datums to define elevations and bathymetry are time-variant and do not have a common zero. This generates slopes between and along the coasts and prevents creation of consistent data sets for global usage.

This paper deals with the chart vertical datum problem and presents a new concept for defining/surveying a time-invariant bathymetry using a high accuracy geoid as the new zero reference surface. Details have also been included on how to realize this zero surface and use the same in real-time navigation. It would also be

necessary to avoid use of different regional or global geoids to maintain consistency in the zero reference.

1. INTRODUCTION

In the complex mapping, charting, and geodetic world, there are hundreds of vertical datums in use. Some datums are properly defined, while in some cases there is hardly any validity in the definition. For many others, information is not available that can be used to determine an accurate height in the local system.

In the above environment, the definitions of the nautical chart datums and the depiction of all other related information useful for safe navigation to avoid underwater and/or overhead hazards vary from one chart to another, coast to coast, between charting agencies, and also between countries. Furthermore, in the hydrographic usages, statements like, "Owing to the many varied tidal characteristics, a precise scientific definition for chart datum, which could be used universally, has not been agreed upon" (IHO, 1993), can still be found. This situation arises due to our age old practice of measuring various time-dependent mean ocean surfaces, such as Mean High Tide (MHT), Mean High Water (MHW), Mean Lower Low Water (MLLW), Mean Sea Level (MSL), Mean Higher High Water (MHHW), Mean Low Water (MLW), Low Water (LW), High Water (HW), etc., and then due to our efforts to use such tidal surfaces in relating them to land and nautical chart datums in depicting heights or ocean depths.

The above approach can and has varied from one country to another country and is dependent on the adopted definitions and tide models, surveying techniques, and durations (for computing "means"), and instrumentation. As the sea level changes can be excessive and are also time-dependent, the knowledge of accurate tide modeling, which is always complex, becomes critical. Thus, in this complex and difficult to measure time-dependent scenario, it is quite obvious why internationally it would be difficult to agree to a common datum for nautical charts and ocean depths.

However, we now have the capability to compute a geoid of very high accuracy over ocean areas and thus define an accurate nautical chart vertical datum without using time-dependent tidal surfaces. Also, the availability of the Global Positioning System (GPS) makes it easy to establish this vertical datum for chart by surveying time-invariant depths in the field and then depicting them on charts. Then, reversing the survey mode, these charted depths can be realized in real-time during navigation to check depth clearances to avoid ship grounding.

This paper presents a new concept to define a nautical chart vertical datum completely independent of time, to establish the same through GPS surveys, and also to realize the seafloor depths during navigation. The approach thus eliminates

the necessity for the time-dependent sea level and other tidal data as the primary source of information for navigation.

2. CURRENT TIDAL LEVELS

Figure 1 shows an illustrative depiction to define various tidal levels and charted data as this information is currently in use by some countries (NOAA, 1990), if not by all. For example, use of the Lowest Astronomical Tide (LAT) as the vertical datum in charts is increasing. There are some interesting conflicts and deviations between various definitions in Figure 1. Mariners using the data based on these definitions would have a hard time understanding and correctly interpreting them, especially when hard pressed for time and faced with little margin of error. A few typical examples of such cases are:

(1) Use of MLLW as chart datum (CD) to depict charted depths versus use of chart LW (drying) line to depict drying heights.

(2) Use of Charted HW (coastal) line as land survey datum to depict charted heights. Here, MSL is shown separately, even though all the land vertical datums worldwide are defined with respect to it.

(3) Both MHW and MHHW are shown differently from the charted HW (coastal) line.

(4) While charted depths are defined with respect to MLLW, the charted vertical clearances are defined with respect to MHW, and not to MHHW. This definition may leave MHHW practically with no application, at least in **Figure 1**.

In **Figure 1**, the "height of tide" is defined with respect to MLLW (CD), while Tide and Current Glossary (NOAA, 1989) does not define this important item. Further, this glossary includes Half-Tide Level, also called Mean Tide Level, to define a tidal datum which is midway between MHW and MLW; but the same is not included in **Figure 1**.

Table 1 (NOAA, 1990) shows a typical example of a tide table where tidal levels are related to "Datum of Soundings". Here, a user will then have to solve or interpret a newer set of terms like MHWS, MHWN, MLHW, and MHLW. To make the usage of available information more complex and thus more difficult to interpret correctly, the note in Table 1 indicates that the order of the included tidal levels, as referred to all the sounding datums, may be different in national tables. If this statement is taken to correct, the involved definitions of these terms may also be different (IHO, 1993).

Another important aspect in all of the above complexity of terminology and definitions is that all this information may also be time-dependent.

3. DEFINING TIME-INVARIANT ZERO REFERENCE SURFACE

On land, the orthometric heights or elevations are defined theoretically with respect to the geoid. However, in the past, due to our limitations to compute and establish the geoid with the desired accuracy, the Mean Sea Level (MSL) was and still is used to approximate the geoid, though the MSL does not coincide with an equipotential surface. Another complication in using MSL to define a vertical datum is that it deviates from coast to coast, both in east-west and north-south directions. There are cases when the MSL has been very poorly "meaned" in defining zero surface for the vertical datums and related elevations. In ocean areas, the bathymetric data, as available currently, is related to a zero reference surface which may be even more poorly defined than MSL for the land areas.

In view of our present capability with the newer technology and availability of accurate observed data sets, the geoid over ocean areas can now be computed easily with absolute accuracy of about ± 25-30 cm. All indications reflect that this accuracy may be even better in the near future.

It is thus proposed to utilize the geoid as the zero surface for the nautical chart datum and reference all bathymetric data to it. This referencing will then provide a time-independent and globally consistent definition and facilitate easy integration of different data sets which would originate from newly surveyed projects under this definition.

Another important point, which requires clarification under the proposed concept, is that the geoid (to be used) is defined by the following equation:

$$W(X,Y,Z) = W_0 \qquad (1)$$

where the "W" is the earth's total gravity potential and "W_0" the geoid constant as specified by the International Association of Geodesy (Moritz, 1980). The computational task of such a high absolute accuracy geoidal solution using extensive data sets with coverage from all over the globe would be a very costly and time consuming effort. To eliminate conflicts between too many zero surfaces arising from the use of regional geoidal solutions will have to be avoided. In addition, to ensure consistent accuracy, worldwide proliferation of too many solutions must be checked. To achieve these two desirable goals, international institutions like the International Hydrographic Organization, International Maritime Organization, International Commission on Geoid, and

International Federation of Surveyors would play an important role in coordination and adoption of an accurate global geoidal solution by all.

4. SURVEYING CONSISTENT BATHYMETRY

Figure 2 illustrates a typical survey scenario using GPS. In open and deep ocean areas, where accuracy of measured depths will be less critical, the ellipsoidal height (h) of the ship can be determined with GPS in navigation or single point positioning mode. As the survey scenario would approach the coast with shallower water depths, high accuracy requirements would also become more critical. In such cases, the ship's ellipsoidal height (h) would be established or surveyed with differential GPS technique where the survey can be designed to achieve desired higher accuracies in "h".

The surveyed ellipsoidal heights (h) of the ship can provide the h_P of the sea surface, which when combined with the computed geoidal height (N_P), would give the orthometric height (H_P) as:

$$H_P = h_P - N_P \qquad (2)$$

Then, at the same epoch, the ship measures through sounding the distance S_P. Combining the S_P with sea surface orthometric height H_P (using equation 2), the depth D_P can be computed as:

$$D_P = S_P - H_P \qquad (3)$$

While the surveyed h_P and S_P and computed H_P would be time variant with the moving sea surface, the geoidal height (N_P) and computed depth (D_P) would be time-independent. Further, as the heights h_P and N_P would be established in the globally consistent World Geodetic System (WGS) 1984 used by GPS, the computed depth D_P through ship's soundings would also be defined with respect to the WGS 84 geoid (DMA, 1991).

Once an area is surveyed with all the depths referenced to the WGS 84 geoid, the information can be utilized to contour the nautical charts. The data can also be stored as individual depths in a digital data base and will also be available for use with digital charts.

5. RECOVERING DEPTH AND HEIGHT CLEARANCES DURING NAVIGATION

a. Depth Clearance :

While navigating in an area with its nautical chart plotted and contoured for depths (Section 3.), the height (Hp), using the GPS surveys and the computed geoidal height (Np), depth (Dp) and the ship's hulk (HL) are configured in **Figure 3.**

A measure of depth clearance (or the safe distance between the ship's bottom and the seafloor) will then be given as :

$$HL < Hp + Dp \qquad (4)$$

A new measurement of sounding (Sp) at the sailing time will then provide a check on the plotted depth Dp on the chart.

b. Height Clearance :

While navigating in an area with its nautical chart plotted for height clearance, the height (Hp), using the GPS surveys and the computed geoidal height (Np), the height (H_B) of a bridge and length of the ship's mast (HM) are configured in **Figure 4.**

A measure of height clearance (or the separation between the highest point of the ship's mast and the bridge bottom) will then be given as :

$$HM < H_B - Hp \qquad (5)$$

It is important to point out that the distance from the sea surface to the GPS antenna would be a measured correction in all of the above relationships.

6. RELATING THE TIDAL SURFACES

At any tidal station, the absolute zero of the tidal staff can be established with the GPS absolute point positioning survey at a nearby station and then performing differential leveling to the staff (**Figure 5**). Its orthometric height H (≈ h - N) set to the geoidal zero will be consistent all over the globe.

Then, all the tidal surfaces, e.g., MLLW, MLW, MSL, MHW, can be surveyed with respect to the zero of the tidal staff or to the geoid and used with consistent definition worldwide as auxiliary information with the time-invariant bathymetry.

Though the tidal surfaces will be tied to the same zero as the elevations and depths determined with the GPS surveys and a global geoid, it is emphasized that

the tidal measurements and/or reductions would not be required when navigating with GPS fixings and using depths which are referenced to the geoid. In this mode, the ship navigator can use the high tide information as auxiliary data to compute the "safe" time when the high tide would improve ship's clearance to entering the shallower areas.

7. EVALUATING THE NEW CONCEPT

The proposed use of the geoid as the zero reference for a global vertical datum will enable us to integrate and analyze the depth and elevation data over the sea and land interface. It will also eliminate the numerous existing local tidal datums which are in use around the world.

However, the adoption of a new vertical datum would raise an immediate issue of what to do with the existing data sets based on the numerous tidal datums, each with its own definition and how to save this valuable information.

One solution for the integration of the existing data sets is datum transformations but this method would not improve the quality and accuracy of the data based on the numerous tidal and chart datums. However, it would definitely help in utilizing the existing information until the new and more accurate data sets are surveyed and integrated under consistent, time-invariant, and accurate definition.

It is also noted that the proposed method to determine the depths with respect to the geoid also involves the sounding data and the accuracy of final results would require accurate acoustic modeling. As the issue concerning the accuracy of the soundings is not a new one, the improvement in the acoustic modeling should be considered as an area for future research (Section 5.).

8. ACCURACY ESTIMATION

In **Figure 2**, in offshore areas the ellipsoid height (h) can be surveyed using differential GPS with an accuracy of ± 1 meter in routine field surveys. Also, the achievable accuracy of the geoid over ocean areas would be within the desired range of about 25 cm in the near future, even though some doubts may still exist about the accuracies of the current geoidal model(s).

The above two estimates shift the emphasis to the sounding measurements and their surveyed accuracy which would impact the final accuracy of the bathymetric data. **Table 2**, extracted from a National Oceanic and Atmospheric Administration publication (NOAA, 1978), is one such example which specifies the accuracy standards for measurement of soundings during field surveys. Another very important document, which specifies

international standards and classification criteria for hydrographic surveys and soundings, is the IHO Special Publication No. 44 (IHO, 1987).

Though the above table or the IHO publication specifies the desired accuracy requirements, standards, and classifications for soundings and related hydrographic surveys, the users would still be concerned about the accuracy actually achieved and/or obtained during any marine field survey over an area, especially when one would consider all the rapidly varying environmental conditions and use of different definitions. Thus, under the newly modified and more accurate survey scenarios with GPS techniques, the new concept of using a global geoid as zero reference would be very timely. Further, the measuring of ship's soundings with modern instrumentation, a complete revision of achievable accuracies and specifications for the GPS and marine surveys and soundings, and setting of new international standards would also become an immediate necessity.

9. SUMMARY

The practical complexity and difficulties arising from the use of numerous vertical datums and various time-dependent tidal surfaces with inconsistent definitions are impeding the correct integration of valuable information. This also affects safe navigation over international waters.

The new concept of the geoid as the zero reference surface for the time-invariant bathymetry and elevations is practical and also realizable with sufficient accuracy using current technology and available data sets. The computation of a modern global geoid with an absolute accuracy of ± 25 cm is a costly project, but to accomplish the same at this time would be very timely. Problems arising from use of various relative and regional solutions and also of different global geoids with lower accuracies would have to be avoided. Use of local geodetic datums for differential GPS surveys would be another dangerous and critical problem. If the new survey data is not properly coordinated and collected under standardized specifications, the present complexity may crop up in a different form.

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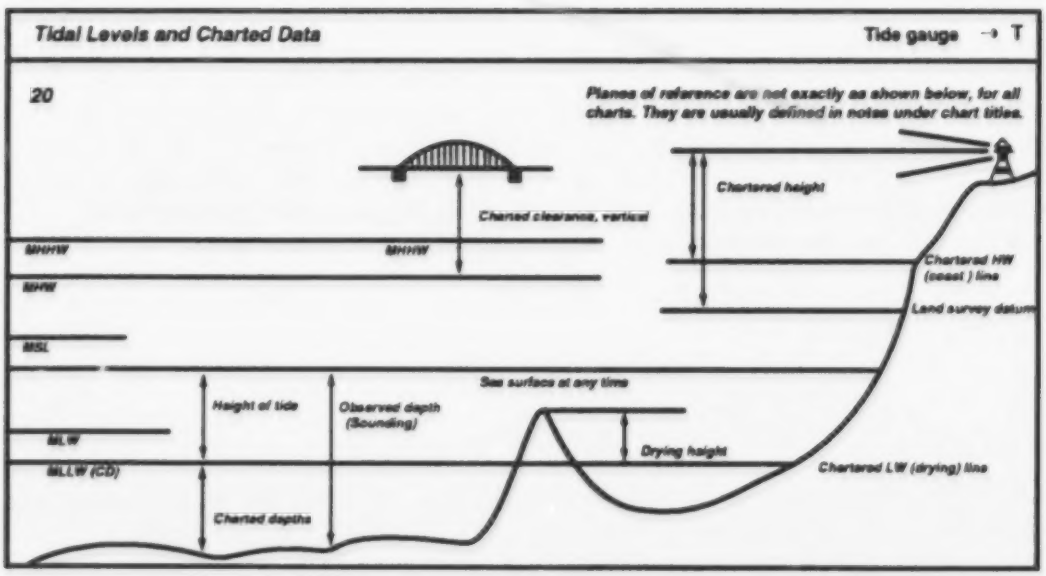
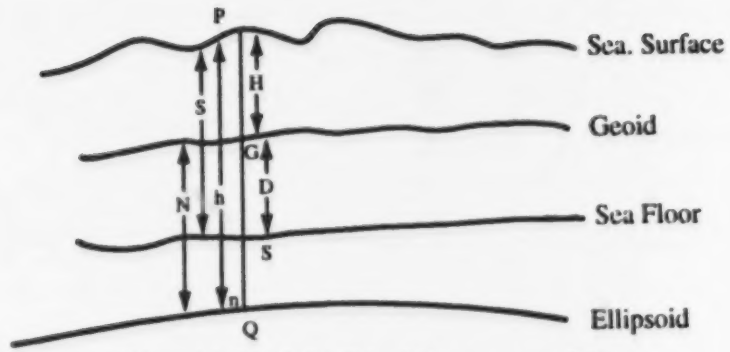


Figure 1. Tide Levels and Charted Data (NOAA, 1990)

/...



PQ = Ellipsoidal height (h) of the survey ship surveyed with GPS

QQ = Geoidal height (N) computed with the Earth Gravity Model (EGM)

PS = Sounding (S) measured acoustically from the survey ship

GS = Depth of sea floor (D) from the geoid

Figure 2. Surveying the Time-Invariant Bathymetry

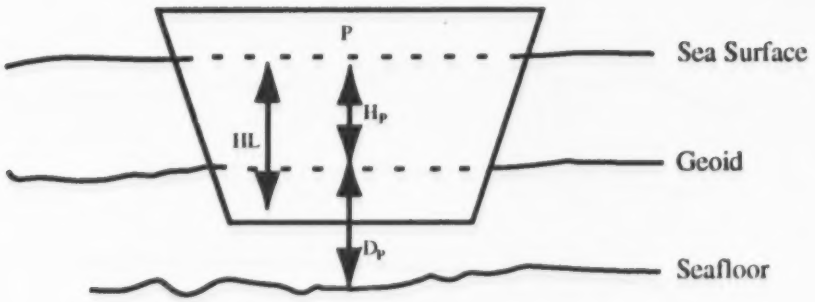


Figure 3. Surveying the Depth Clearance

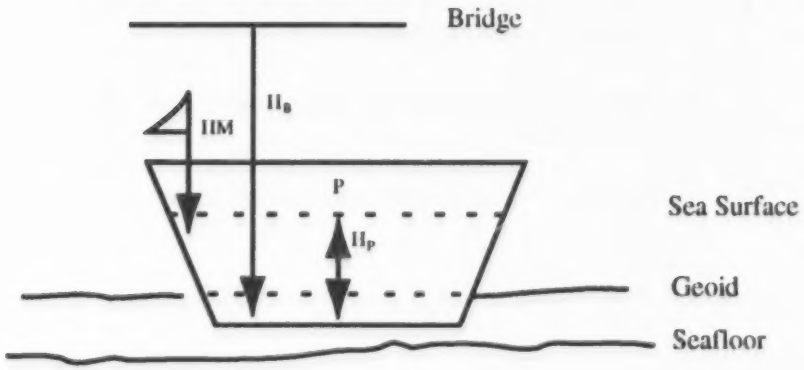


Figure 4. Surveying the Height Clearance

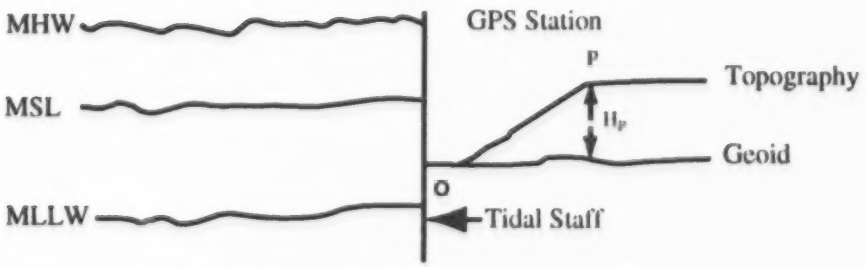


Figure 5. Surveying the Zero Height of the Tidal Staff

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Table 1[1]

Tide Tables Referred to Datum of Soundings

30	Tidal Levels referred to Datum of Soundings Place / Lat N / Long E / Heights in meters above datum: MHWS, MHWN, MLWN, MLWS; MHHW0, MLHW, MHLW, MLLW		*Tabular statement of semi-diurnal or diurnal tides* *Note: The order of the columns of levels will be the same as that used in national tables of tidal predictions.*
31		*Tidal Stream table*	Tidal streams referred to: Hours / Geographical Position Before High Water 6 5 4 3 2 1 High Water 1 After High Water 1 2 3 4 5 6 Directions of streams (degrees) Rates at spring tides (knots) Rates at neap tides (knots)

1 NOAA, 1990.

/...

Table 2[1]

Accuracy Standards for Soundings

Water Depth	Allowable Errors
0 - 20 meter	0.3 meter
20 - 100 meter	1 meter
> 100 meter	1% depth

1 Extracted from NOAA, 1978.

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Item 6 (b) of the provisional agenda*

REPORTS ON THE CONTRIBUTION OF SURVEYING, MAPPING AND CHARTING TO SUPPORT THE IMPLEMENTATION OF AGENDA 21: PUBLIC ACCESS TO AND EXCHANGE OF INFORMATION

National Electronic and Multimedia Atlases: A New Cartographic Product for the Information Era**

(Submitted by the International Cartographic Association (ICA))

* E/CONF.89/1.

** Prepared by Prof. D. R. F. Taylor, Past President, International Cartographic Association, Department of Geography, Carleton University, Ottawa, Canada.

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NATIONAL ELECTRONIC AND MULTIMEDIA ATLASES: A NEW CARTOGRAPHIC PRODUCT FOR THE INFORMATION ERA

Introduction

The information revolution is having a profound impact on cartography. This paper will consider a new product as an example--the Electronic National Economic Atlas of China (ENEAC) which was produced in CD-ROM form in November of 1996 and which is now commercially available.

Electronic atlases are very much a product of the 1990s and there are a number of examples appearing at various scales. The Electronic Atlas of Canada, which is now online on the World Wide Web, and the Electronic Atlas of Sweden are good examples of this new genre which has great potential for the future. The Electronic National Economic Atlas of China is the first comprehensive and completeelectronic atlas produced by a developing nation and is a truly remarkable product.

The National Economic Atlas of China published in 1994 is one of the most impressive national atlases ever produced in traditional paper format. It is also probably the last major national atlas of its type. The first true major national atlas produced was the National Atlas of Finland published in 1899 at the close of the 19th century. As the 20th century draws to a close it is unlikely that any new major national atlases in paper format will be produced. There are a number of reasons for this. The economics of atlas production in traditional format have changed making the costs of such production exorbitant. More importantly, however, are the technological changes of the information era where the convergence of computer, broadcast and telecommunication technologies and media is revolutionizing cartography and most other aspects of human activity all over the world. We are entering the era of the electronic atlas with an emphasis on dynamism and interaction rather than static map production.

The publication of the National Economic Atlas of China was a remarkable achievement in both relative and absolute terms. It gives a comprehensive graphic picture of the most populous nation on earth and is a major contribution to our understanding of one of the most remarkable economic and social changes of our time--the ongoing transformation of a dominantly agricultural society into a modern industrial economy. The Atlas, however, suffers from the major disadvantage of all products of its type. It was outdated by the time it was published and, in addition, it is essentially a static document.

The Electronic National Economic Atlas of China is an entirely new product and reflects the changes which are taking place in modern cartography. It is new in two important ways. First, the data it contains are new. The remarkable pace of change in China's economy continues with little indication of any significant slow down.

Although China's physical geography remains fairly constant and basic spatial patterns persist almost everything else is changing. The National Economic Atlas of China was published in 1994 but much of the data on which its maps were based were at least five years old. The base data for the Electronic Atlas is from surveys completed in 1993 and much of the data is from 1994 and 1995. Unlike the paper version the format of the Atlas allows easy update at low cost.

The second important way in which the Electronic Atlas is different is the degree of interaction and choice which is open to the user, through the access software developed for the Atlas--EA WORLD. In the paper version of the Atlas all users were constrained by the linear format. Although a user could choose a particular map to view by turning the pages, all users would see the same image on that page. In the Electronic Atlas it is unlikely that any two users will use the Atlas in exactly the same way. The software uses an object oriented approach and is not linear in nature thus allowing great flexibility. Although the software was developed for use with this Atlas it can easily be adapted for use with other electronic atlas projects and is a major contribution to the field of electronic mapping. The importance of a good user interface cannot be over-emphasized.

Visualization (MacEachren and Taylor, 1994)[2] is central to modern cartography. Although visual analysis and communication have always been important aspects of cartography, modern visualization is different in both quantitative and qualitative terms. In quantitative terms many more products, such as electronic atlases can be produced much faster and much more cheaply. This Electronic Atlas, for example, was produced in less than half the time required for the paper product and at a fraction of the cost. In qualitative terms interaction with visual displays can take place in real time greatly increasing the comprehension of the user in a wide variety of subject areas. It is this marked increase in the possibilities for cartographic cognition and analysis which is at the heart of cartographic visualization resulting in an exciting and dynamic cartography with interactive manipulation of spatial data leading to increased understanding of complex situations. The volume of spatial data becoming available is increasing exponentially and the data in this Atlas is an example. To fully use the interface options available with each of the 250 maps would take countless hours of continuous use. The paper Atlas was designed to be comprehensive and to be used in a comprehensive way. The Electronic Atlas is designed to be even more comprehensive in terms of information but to be used in an selective way with the user focussing in on topics of special interest. In a paper atlas the user gets only what the cartographer chooses to display. In an electronic atlas the user can go well beyond the images displayed and in some instances to the original data from which the images were compiled.

Scale is also no longer as major a constraint in the electronic era. The possibility of zooming in on areas of special interest at

larger scales now gives much more flexibility although there are still, of course, limitations on how much scale change can be achieved without an unacceptable loss of accuracy. In the Electronic National Economic Atlas of China the zoom function is particularly useful for thematic data at the county level.

This Atlas is produced on CD-ROM but already a growing volume of map information is being made available to users on the World Wide Web. In September 1994 selected elements of the National Electronic Atlas of Canada were made available on the Web and within a month over 60,000 users from over 40 countries had accessed the images (Taylor 1995)[3]. As the information superhighways form and expand, direct delivery of map and spatial information into the home will become more common.

Another major tool is the development of multimedia electronic atlases in which a wide variety of media such as sound, music, film and animation can be integrated with the map data in new and exciting ways. There are already a number of such atlases on the market.

Data Sources

The wealth and volume of information that the atlas contains on China is unique. Seven major sources of information have been used to compile the data for the Atlas. The most authoritative data on population in China is the Fourth National Population Census of 1990. The data are of a high level of quality and accuracy and are available at the county level for rural areas and at a larger scale within China's major cities. Also available at the county level are data from China's Rural Social Economic Statistics from a major survey held in 1993. For each county 190 indicators of the rural economy and agricultural production have been collected. For each of China's cities information is available on over 370 indicators on economic and social development and the rapid expansion of urban construction. Much of the basic information is from 1993. China's industrial sector is growing in size and complexity and there are important changes in ownership and structure as the socialist market economy develops. Data for 1995 for the ongoing National Tertiary Industry Survey have been used for the Atlas and these have been complemented by the latest statistics on an enterprise by enterprise basis of all of China's large and medium scale industrial enterprises. Much of thedata is from 1993 and includes production and investment statistics. This Atlas also utilizes the Statistical Yearbooks of China for the related provinces, autonomous regions and municipalities under the direct administrative control of the Central Government published by the National Statistical Bureau. A final major major source of data for the Atlas is special survey statistics produced by individual ministries on health, education, scientific research, foreign trade, post and telecommunications, rail traffic and environmental protection.

Each of these data sets is important in its own right but their combination and presentation in spatial format greatly increases their value and utility and the data base available in the Atlas is by far the most comprehensive data base available on China in digital format. As the data have been coded and organized in spatial format, comparisons and combinations of different data sets by spatial units as detailed as individual counties are relatively easy. The format ofthe Atlas also allows update on an annual basis and the Atlas will be regularly updated, initially on a biennial basis.

Atlas Content

There are ten topic sections in the Atlas which has over 250 map themes and over 1000 graphs, diagrams, indices and accompanying materials. The ten sections cover:

1. Administrative Divisions and Topography
2. Resources
3. Population
4. General Economy
5. Agricultural and Rural Economy
6. Industry--which is the largest single component of the ENEAC
7. Transportation, Post and Telecommunications
8. Buildings, Urban Construction and Environmental Production
9. Trade, Commerce, Financial Institutions and Tourism
10. Education, Scientific Research, Culture and Sports

The data base is large, taking up between 300 and 400 megabytes of computer memory.

Hardware Requirements

The atlas is designed to run on a PC in a Microsoft Windows environment. Requirements include 4 megabytes on memory, 120 megabytes of hard drive on 8 bit VGA adaptor with 256 colours and a colour screen monitor with a resolution of 768 X 1024. Hard copy requires a colour laser or ink jet plotter for best results.

Software

Access to the information in the Atlas is through a software package called EA-WORLD which is an integral part of the Atlas package. The software was developed indigenously in China by the Institute of Geography of the Chinese Academy of Sciences. An object oriented approach was used using a modified Hypertext concept. A detailed description of the approach used can be found in Taylor, Liu and Chu' and is beyond the scope of this paper. Utilizing the query and display function of EA-World which is knows as EA-Viewer, the main functions are:

1. Map display and zoom in and out
2. Map roam
3. Map display by theme or two map contrast display

4. Dual direction query and multiquery; retrieving cartographic indices by geographic position or obtaining spatial distributions through logical expressions of cartographic indices.
5. Display of st tistical data by theme
6. Selected thematic data output to printer
7. Hard copy of maps through printer
8. The retrieval and output of explanatory Atlas text and notes

Conclusion

The Electronic National Atlas of China is a major contribution to the field and is a clear example of China's interest in the information era. The Atlas was conceived, developed and produced in China utilizing indigenous sources and expertise. The Atlas is a tribute to the ingenuity, skill and expertise of Chinese cartographers. It provides in a remarkable way a picture of a remarkable nation undergoing an economic and social transformation of unparalleled scale and significance. For nearly two decades the economy of China has developed on an average growth rate of over nine percent. This far exceeds the growth rate of the nations of Western Europe during the Industrial Revolution and is much more impressive and sustained than the more recent "Japanese Economic Miracle" of the 1950's and 1960's. Growth is, of course, not without its problems, including growing interpersonal and spatial disparities which the Atlas reveals, and a rise in inflation rates which detracts from overall growth. Population growth rates, although modest in percentage terms, are significant because of the large population base. An added concern is that the rapid pace of industrialization is causing a loss of farm land which may have adverse effects on food production, which is vital to China's future. Although these cannot be ignored, the picture which emerges from the Atlas is of a nation poised to be a major player on the world scene for the 21st century.

China has indicated to the developing world what can be achieved in terms of electronic atlas production. ENEAC is a sophisticated interactive produce with an immense and comprehensive data base on China's economy. The next generation of atlases of this type will be full multimedia products. A good example is Canadian Geographic Explorer which was produced by a consortium of government and private sector enterprise. The CD-ROM utilizes maps, photography, video, text, remote sensed imagery and digital terrain models. Explorer is designed for the general public and makes imaginative use of sound and imagery including the first 3D remote sensed imagery and the CD-ROM comes with special viewing glasses. ENEAC is a sophisticated product but is designed for the knowledgeable user. Explorer can be used by novice and expert alike and is an excellent method of informing the general public of the geography of a nation in an inexpensive and usable form. It is interactive and allows full scope for user choice but at the same time is structured so that the user has a definite path along which to navigate and make choices. The CD-ROM will persist as a delivery mechanism for new forms of atlases for some time but increasingly products will become available on networks such as the INTERNET.

These networks are likely to be supplemented by new forms such as INTRANETS and EXTRANETS which some national mapping agencies may wish to explore in terms of delivering products to their customers. The map, in new forms, will remain central to the information era.

Notes:

1. The author would like to acknowledge the generous support of the Max Bell Foundation, Toronto, Canada which made his participation in the Atlas possible.

2. MacEachren, A. J. and D. R. F. Taylor (eds), (1994) Visualization in Modern Cartography, Volume 2 in Modern Cartography Series (D.R.F. Taylor, series ed), Oxford, New York, Tokyo: Elsevier Science, pp. 345.

3. Taylor, D. R. F. (1995) Presidential Address to the 10th General Assembly of the International Cartographic Association, Barcelona, Spain.

4. Taylor, D. R. F., Liu Yue, Chu Shiqiang (1996) "EA-World: An object oriented software package for the design and use of hypermedia electronic atlases, Institute of Geography, Chinese Academy of Sciences, Beijing, People's Republic of China.